Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

SHOUT
SHARE
IT

U. S. DEPARTMENT OF AGRICULTURE.
DIVISION OF ENTOMOLOGY.
BULLETIN NO. 10.
(SECOND, REVISED EDITION.)

OUR SHADE TREES AND THEIR INSECT DEFOLIATORS.

BEING A CONSIDERATION OF THE FOUR MOST INJURIOUS SPECIES WHICH AFFECT THE TREES OF THE CAPITAL; WITH MEANS OF DESTROYING THEM.

BY

C. V. RILEY,
ENTOMOLOGIST.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1888.
21061—Bull 10

CONTENTS.

	Page.
Letter of submittal	5
Introduction	7
Four Principal Leaf-eaters	8
THE IMPORTED ELM LEAF-BEETLE	8
AN IMPORTATION FROM EUROPE	8
HABITS AND NATURAL HISTORY	8
REMEDIES	11
MORE RECENT EXPERIENCE AT THE DEPARTMENT	14
Past history of the elms in question	14
Condition and characteristics of the grove in 1882 *and* 1883	14
Extent of injury in 1882 *and* 1883	14
Preference of the elm beetles for certain varieties	15
Effects of arsenical poisons on insect and plant	15
Preventive effects of the poison	16
Treatment with London purple	17
Preparation of the poison	17
Effects of the mixture	17
Treatment with Paris green	18
Mechanical means of applying the poison	19
THE BAG-WORM	23
HABITS AND NATURAL HISTORY	23
The eggs	23
The larva and its bag	23
Pupation	25
The imago or perfect insect	25
GEOGRAPHICAL DISTRIBUTION	26
FOOD-PLANTS	27
ENEMIES	27
THE WHITE-MARKED TUSSOCK-MOTH	29
HABITS AND NATURAL HISTORY	29
The eggs	29
Development and characters of the larva	29
Habits of the larva	30
A new form of Orgyia attack	30
Pupation	32
The imago	32
Hibernation	33
Number of annual generations	33
FOOD-PLANTS	33
NATURAL ENEMIES AND PARASITES	33
GEOGRAPHICAL DISTRIBUTION	35
THE FALL WEB-WORM	36
NATURAL HISTORY	36
Limitation of broods	36
The eggs	37
The larva	38
Pupa and cocoon	39
The moth	39
INJURY DONE IN 1886	40

Page.

Four Principal Leaf-eaters—Continued.
THE FALL WEB-WORM—Continued.
PROPORTIONATE INJURY TO DIFFERENT PLANTS AND SHADE-TREES 43
PECULIAR EFFECT OF DEFOLIATION UPON SOME PLANTS 45
ENEMIES OF THE WEB-WORM OTHER THAN INSECTS 46
PREDACEOUS INSECT ENEMIES 47
FUNGUS DISEASES OF THE WEB-WORM 49
Experiments to obtain percentage of diseased caterpillars. 50
TRUE PARASITES OF THE WEB-WORM 51
Telenomus bifidus Riley 51
Meteorus hyphantriæ Riley 52
Apanteles hyphantriæ Riley 53
Limneria pallipes Prov 55
Tachina sp 55
SECONDARY PARASITES 57
Summary of the habits of the four species 59
Remedies and preventive measures 61
WINTER WORK 61
ONE SIMPLE PREVENTIVE REMEDY FOR ALL 61
PRUNING AND BURNING 65
MULCHING 66
INFLUENCE OF TREE-BOXES 66
WHITEWASHING OF TRUNKS 67
Birds: The English Sparrow 68
The future of our trees—Pruning 69
Trees which are uninjured 70
Good and bad effects of our trees 70
Prospects the coming season. Conclusion 71
INDEX 73

LETTER OF SUBMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., March 15, 1887.

SIR: I have the honor to submit for publication Bulletin No. 10 of this Division, being an account of the more important insects which defoliate our shade trees. While of interest to other sections of the country, it has been prepared primarily to supply the constant demand for information by residents of the National Capital. In the series of Bulletins of this Division it takes the place of one on "Bird Migration in the Mississippi Valley," announced a year ago, and which, since the creation of the separate Division of Ornithology and Mammalogy, I have thought best to leave out of the series from the Entomological Division, especially as Dr. Merriam, the Ornithologist, has greatly amplified it.

Respectfully,

C. V. RILEY,
Entomologist.

HON. NORMAN J. COLMAN,
Commissioner of Agriculture.

INTRODUCTION TO THE FIRST EDITION.

Though all four of the insects considered in this Bulletin have been studied in years gone by and have been treated of in various publications, yet some facts of interest are recorded here for the first time. The article on the Elm Leaf-beetle is reproduced from Bulletin No. 6, which has been for some time out of print. Those on the Bag-worm and on the Tussock-moth are condensed from our First Report as State Entomologist of Missouri, published in 1868, and from later writings, and that on the Fall Web-worm is made up from the Third Report of that series for 1870, but contains much that is new and especially applicable to the District of Columbia, the quoted portions being taken in advance from our forthcoming report to the Department. The Bulletin concludes with some facts and suggestions which are also of local interest and have been elicited by the exceptional concern shown by the people of Washington in the caterpillar nuisance. Some portions of this part of the Bulletin have been given for publication to the Washington *Evening Star*.

In treating of the means of preventing the injury and of preserving the foliage of our trees we have gone into details as to the most important means in considering the first species, or the Elm Leaf-beetle, so as to avoid repetition, and later, in connection with the fourth species or Fall Web-worm, referred briefly to other methods.

C. V. R.

SHADE TREES AND THEIR INSECT DEFOLIATORS.

FOUR PRINCIPAL LEAF-EATERS.

There are four insects principally concerned in the defoliation of the shade trees in the city of Washington. They are: (1) The Imported Elm Leaf-beetle (*Galeruca xanthomelæna*); (2) the Bag-worm (*Thyridopteryx ephemeræformis*); (3) the White-marked Tussock-moth (*Orgyia leucostigma*); and (4) the Fall Web-worm (*Hyphantria cunea*).

THE IMPORTED ELM LEAF-BEETLE.

(*Galeruca xanthomelæna** Schrank.)

The depredations of this pest have now become widely extended throughout the Northeastern States, rendering almost worthless and unsightly those most valuable shade trees of our cities—the elms. As its injuries are so far unknown in the Mississippi Valley, the blighted appearance of the elms on the Department grounds in midsummer, and especially of the European varieties, at once attracted our attention when we first came to Washington, and a series of experiments was begun with a view of checking the ravages of the insect. The excellent opportunites thus offered for experiment and study have since been improved, and, with some prefatory passages in relation to the history and habits of the beetle, we will give the practical results reached.

AN IMPORTATION FROM EUROPE.

This beetle has done great mischief in the Old World, especially in Germany and France, and it is very important that the public know the best method of coping with it here. According to Glover, it was imported as early as 1837. Its distribution was formerly confined to limited areas near the coast, and its earlier attacks were notably about Baltimore and New Jersey.

HABITS AND NATURAL HISTORY.

The general characteristics of this insect have been pretty well studied abroad. Mr. E. Heeger† has given an excellent account of its life-history, with a detailed description of the larva and figures illus-

* This is the *Galeruca cratægi* Först., and *G. calmariensis* Fabr. In Crotch's Checklist it appears as *Galerucella xanthomelæna*.

† Seventieth contribution to the natural history of insects. Sitzungsberichte der kais. Ac. Wiss., Wien, 1858, vol. 29.

trating larva and pupa, and anatomical details. More recently M. Maurice Girard* has given a rather poor wood-cut illustration of the insect and its work, with the leading facts concerning its nomenclature and natural history as observed in Europe. Biological notes on the insect have also been given by Leinweber† and Kollar.‡

FIG. 1.—*Galeruca xanthomelana*; *a*, eggs; *b*, larvæ; *c*, adult; *e*, eggs (enlarged); *f*, sculpture of eggs; *g*, larva (enlarged); *h*, side view of greatly enlarged segment of larva; *i*, dorsal view of same; *j*, pupa (enlarged); *k*, beetle (enlarged); *l*, portion of elytron of beetle (greatly enlarged).

In our country the life-history of the insect and its injury have been referred to by Harris, Fitch, Morris, Walsh, and ourselves, while the agricultural papers contain numerous references to the injury inflicted by the insect. The perfect beetle has often been described in systematic works on Coleoptera.

For these reasons we deem it unnecessary to enter here into a detailed description of the beetle and its earlier stages, but content ourselves with pointing out the more obvious characters, alluding to such facts of the life-history as are necessary to a full understanding of the nature of the remedies to be applied for this pest.

The eggs are deposited in an upright position upon the under side of the leaves (Fig. 1 *a*), always in a group, consisting generally of two, rarely three, more or less irregular rows. The individual eggs are close

* Note sur la Galéruque de l'orme, Bull. d'Insectologie Agricole, VIII, pp. 113–116.

† Verhandlungen zoöl.-bot., Ges., Wien, 1856, VI, Sitzb., pp.74, 75.

‡ *Op. cit.*, 1858, VIII, pp.29, 30.

together in each group (Fig. 1 *e*, magnified), and so firmly fastened to the leaf that they can only be detached with great care without breaking the thin and brittle shell. The number of eggs in each group varies from four or five to twenty or more. Very rarely only three eggs are seen in one group, but we never found less than that number. The egg itself is oblong, oval, obtusely, but not abruptly, pointed at tip, of straw-yellow color, its surface being opake and beautifully and evenly reticulated, each mesh forming a regular hexagon, as shown, highly magnified, in Fig. 1 *f*. The form of the eggs is not quite constant, some of them, especially those in the middle of a large group, being much narrower than others. The duration of the egg-state is about one week.

The general shape of the larva is very elongate, almost cylindrical, and distinctly tapering posteriorly in the early stages, but less convex, and of nearly equal width when mature. The general color of the young larva is yellowish-black, with the black markings comparatively larger and more conspicuous, and with the hairs arising from these markings much longer and stiffer than in the full-grown larva. With each consecutive molt the yellow color becomes more marked, the black markings of less extent and of less intense color, and the hairs much shorter, sparser, and lighter in color. A nearly full-grown larva is represented in Fig. 1 *g*, and in this the yellow color occupies a wide dorsal stripe and a lateral stripe each side. The head (excepting the mouth parts and anterior margin of the front), the legs (excepting a ring around the trochanters), and the posterior portion of the anal segment, are always black. The first thoracic segment has two large black spots on the disk, of varying extent, and often confluent. The following segments (excepting the anal segment) are dorsally divided by a shallow transverse impression into two halves, and the black markings on these halves are arranged as follows: Two transversal dorsal markings, usually confluent, as shown in our figure; two round and sublateral spots; the tips of the lateral tubercles are also black. The abdominal joints of the ventral surface have each a transverse medial mark, and two round sublateral spots of black color. Stigmata visible as small umbilicate spots between outer sublateral series of dorsal markings and lateral tubercles. The yellow parts of the upper side are opake, but those of the under side shining. The black markings are polished, piliferous, and raised above the remaining portions of the body.

The larvæ are destructive to the foliage from the month of May until August. They have about two weeks of active life between the egg and pupa states. During this time they prey upon the leaves, which become skeletonized, leaving the venation, and commonly a certain portion of the flesh of the leaf, which becomes rust-brown. They undergo four molts, respectively observed at Washington on July 15 (at hatching) 20, 23, and 29 (pupation). When full grown they descend to the ground and change to pupa under whatever shelter is near to the base of the tree.

The pupa (Fig. 1 *j*) is of a brighter color than the larva, oval in shape, and strongly convex dorsally. It is sparsely covered with moderately long but very conspicuous black bristles, irregularly arranged on head and thorax, but in a transverse row on each following segment. The pupa state lasts about from 6–10 days.

The perfect beetle (Fig. 1 *c*, natural size; *k* magnified) resembles somewhat in appearance the well known striped cucumber-beetle (*Diabrotica vittata*), but is at once

distinguished by the elytra not being striate-punctate but simply rugose, the sculpture under high magnifying being represented in Fig. 1 *l*. The color of the upper side is pale yellow or yellowish-brown, with the following parts black: on the head a frontal (often wanting) and a vertical spot; three spots on the thorax: on the elytra a narrow stripe along the suture, a short, often indistinct scutellar stria each side, and a wider humeral stripe not reaching the tip. Under side black, pro and mesosternum and legs yellow, femora with a black apical spot. Upper and under side covered with very fine, short, silky hairs. In newly-hatched individuals the black markings have a greenish tint; the humeral stripe varies in extent.

The beetle assists the larva in its destructive work, but, as usual in such cases, the damage done by the perfect insect is small when compared with that done by the larva. There are three or four annual generations of the insect, according to the character of the season. In the month of September the beetles prepare for hibernation, seeking shelter in hollow trees, in the ground, under old leaves, &c., and remain dormant until the following spring.

REMEDIES.

M. Girard says:

> There is no other means of destruction than to jar the branches over cloths to collect the larvæ and adults which fall. It is also possible when they are on the ground to distribute on them boiling water or steam, or even quick-lime or solution of sulphocarbonate of potassium.

In our own country much more has been accomplished toward practically combating this insect.

In the U. S. Agricultural Report of 1867, Glover suggested the use of oil and tar gutters and other barriers surrounding the base or the body of the tree, devices similar to those used against the canker-worm and codling-moth. He then and afterward (1870) recommended "to place around each tree small, tight, square boxes or frames, a foot or 18 inches in height, sunk in the earth; the ground within the inclosure to be covered with cement, and the top edge of each frame to be covered with broad, projecting pieces of tin, like the eaves of a house or the letter T, or painted with some adhesive or repellant substance, as tar, &c. The larvæ descending the tree, being unable to climb over the inclosure, would change into helpless pupæ within the box, where they could daily be destroyed by thousands. Those hiding within the crevices of the bark of the trunk could easily be syringed from their hiding places." (U. S. Agricultural Report, 1870, pp. 73, 74.) These boxes were carefully tested at this Department, and they worked as described. While coal-tar and other adhesives were recommended, we have found scalding-hot water most convenient for destroying the insects that accumulate in the inclosure or upon the ground elsewhere. Where branches are low and droop near the ground some of the larvæ descend the wrong way and fall off, but shade trees should not be allowed to grow in this low, drooping manner, and under all ordinary circumstances, where the branches are not severely jarred to encourage the insects to drop, the larvæ will descend by the trunk and become captured in the devices here noticed.

Mr. Glover regarded the pupa state as the most favorable in which to kill the insect, as it can then be easily crushed or scalded. Concerning the tobacco treatment he adds that "syringing the trees with strong tobacco water has been tried with some good effect, but the larvæ not touched by the fluid are merely knocked down by the concussion, and, if nearly ready to change into pupæ, effect their transformation where they fall."

In this connection we cannot do better than quote what we published in 1880* in reply to certain statements by Dr. J. L. Le Conte, as follows:

Anent *Galeruca xanthomelæna*, which is becoming more destructive each successive year to the shade elms in our northern towns, a correspondent mentions the following facts:

1. The trees are not all attacked at the same time, but the insect seems to break out from a center, gradually destroying the more remote trees, so that isolated trees remain comparatively free.

2. After applying a band (saturated with fish-oil, petroleum, &c.) to some trees which were about half denuded, found hundreds of the worms stopped both in ascending and descending the trees.

He also propounded the following query:

3. Do the beetles hibernate in the ground, so that they can be poisoned, or are they perpetuated only by the eggs on the trees:

Allow me to add the following subjects for investigation as necessary to the devising of proper remedies against this foreign invader:

4. How soon do the insects appear in the spring; how rapidly do they propagate; and what time is passed in each stage of development?

5. Are the larvæ and beetles eaten by insectivorous birds, or are they protected by offensive secretions, as is the case with *Doryphora 10-lineata*, *Orgyia leucostigma*, and several other noxious insects?

6. What proportion of the brood hibernates, and in what stage, pupa or perfect insect, and where?

If the materials for furnishing answers to these questions are not yet within your reach, will you kindly direct the attention of some of your trusty observers to the subject, so that persons interested in the preservation of the shade trees which are so justly esteemed may be properly instructed as to the measures to be adopted during the next summer.

Very truly, yours,

J. L. Le CONTE,
Philadelphia, Pa.

The above inquiries were received from our esteemed correspondent some time since, and we employ them as a ready means of giving our experience with the beetle.

For the benefit of the general reader it may be remarked that the natural history of this Elm Leaf-beetle is quite similar to that of the well-known Colorado Potato-beetle and of the Grape-vine Flea-beetle. The only deviation in the Elm Leaf-beetle is in the mode of pupation, which rarely takes place in the ground, unless this be very friable, but at the base of the tree or under any shelter that may present itself near the trees, such as old leaves, grass, &c.

(1) The phenomenon here described is doubtless due to the gradual increase in spring from one or more females.

(3 and 6) Like most, if not all, *Chrysomelidæ*, the Elm Leaf-beetle hibernates in the perfect state. As places suitable for hibernation abound, any attempt to successfully

**American Entomologist*, December, 1880, p. 291.

fight this pest in winter time, with a view of preventing its ravages the subsequent season, will prove fruitless. A large proportion of the hibernating beetles doubtless perish, since the insect is comparatively scarce in the earlier part of the season.

(4 and 5) The beetles fly as soon as spring opens, and we have observed the first larvæ early in May,* in Washington, D. C., or some time after the elm leaves are fully developed. The ravages of the insect begin to be apparent with the second generation of larvæ, which appear in June.

In 1878 we made many notes and experiments on the species, and the development of the third and most injurious generation occupied about one month. The numerous pupæ, which in the latter part of August were to be found under the trees, were mostly destroyed that year, partly by continuous wet weather prevailing at the time, partly by the many enemies of the insect. Among these there are *Platynus punctiformis* and *Quedius molochinus*, which feed on the full-grown larvæ when these retire for pupation, and also on the pupæ. The larva of a *Chrysopa* (probably *C. rufilabris*) feeds upon the eggs of the *Galeruca; Reduvius novenarius* sucks both beetles and larvæ on the leaves, while *Mantis carolina* preys upon the beetle. Of the numerous other insects found among the pupæ under the trees, *e. g. Tachyporus jocosus*, sundry spiders, myriapods, &c., several are doubtless enemies of the *Galeruca*, though we have, as yet, no proof of the fact. Many birds were observed on the trees infested by the beetles, but the English sparrow, which was the most numerous, did not feed on the insect in any stage of growth.

The only method of warfare against this pest recommended by European writers is to jar the larvæ down onto sheets, and then in one way or another to destroy them. This may answer for young trees, but is then tedious and but partial. We found that the quickest and most satisfactory way of destroying the insect and protecting the trees was by the use of Paris green and water in the manner frequently recommended in these columns, and London purple will evidently prove just as effectual and cheaper. The syringing cannot be done from the ground except on very young trees, though a good fountain pump will throw a spray nearly 30 feet high. Larger trees will have to be ascended by means of a ladder and the liquid sprinkled or atomized through one of the portable atomizers, like Peck's, which is fastened to the body and contains 3 gallons of the liquid.

The mode of pupation of the insect under the tree, on the surface of the ground, beneath whatever shelter it can find, or in the crevices between the earth and the trunk, enables us to kill vast numbers of the pupæ and transforming larvæ by pouring hot water over them. We found that even Paris-green water poured over them also killed. If the trees stand on the sidewalk of the streets the larvæ will go for pupation in the cracks between the bricks or at the base of the tree, where they can also be killed in the same way. This mode of destruction is, take it all in all, the next most satisfactory one we know of, though it must be frequently repeated.

(2) We have largely experimented with a view of intercepting and destroying the larvæ in their descent from the tree. Troughs, such as are used for canker-worms, tarred paper, felt bands saturated with oil, are all good and the means of destroying large numbers. Care must be taken, however, that the oil does not come in contact with the trees, as it will soon kill them, and when felt bandages are used there should be a strip of tin or zinc beneath them. The trouble with all these intercepting devices, however, is that many larvæ let themselves drop down direct from the tree and thus escape destruction.

In conclusion we would remark that it is highly probable that Pyrethrum powder stirred up in water might be successfully substituted for arsenical poisons, but experiments in this direction have not yet been made. From experiments we have made with dry, unmixed powder, we found that it affects very quickly the larva, pupa, and the perfect insect, but in order to be applied on a large scale and on large trees the powder must of course be mixed in water. There is, however, no danger in the judicious use of the arsenical liquids upon shade trees.

* Some years, in Washington, it is the end of May before any larvæ hatch, and the time varies, of course, with latitude and season.

MORE RECENT EXPERIENCE AT THE DEPARTMENT.

The more recent experience in the destruction of this Galeruca on the Department grounds may now be summed up, the experiments having been intrusted to Dr. Barnard.

Past History of the Elms in question.—According to Mr. William Saunders, of this Department, these trees have been annually attacked by the European Elm Leaf-beetle since they were planted ten years ago, and about one year in three the injury has been severe, resulting in their defoliation, while in other years, as in 1879 and 1880, there appeared comparatively none. In some seasons a second or autumnal set of leaves appeared after the trees had been stripped, and in certain of these instances the second crop of leaves became eaten; but in all cases he thinks the lives of the trees have not seemed to be endangered and they soon repaired the damage done. His belief is also that the pest did not become gradually worse and worse through the series of years during which it has been observed by him, still he regards the attack of 1882 as worse than any known to him before on these trees or others, and he has noticed the effects of this insect since 1850, first in its earliest ravages about Baltimore, and later elsewhere.

Condition and Characteristics of the Grove in 1882 *and* 1883.—However it may be for the past history or future desirability of certain trees in the grove, in 1882 many exhibited various grades of feebleness, and some had dying branches. Indeed, a few of them had a very unhealthy aspect the previous year also. Of course it can be claimed that their unhealthy condition is due to other causes than the insects; and it should be remembered that most are foreign species, each often represented in two or more of its varieties. Here all grow on level ground, whereas in a state of nature some belong to mountainous localities; others to the damp climate of England, &c. Therefore, many of them are growing under abnormal conditions. They exhibit much variety in the relative abundance, size, form, and texture of the leaves. There is also great diversity in the density and form of branching.

Extent of Injury in 1882 *and* 1883.—All the varieties and species of elms in this grove, without exception, were preyed upon by the pest in 1882 and 1883. The insect, however, showed decided preferences for certain individual trees, varieties, or species, stripping some completely before doing more than very slight harm to the leaves of others, the former becoming completely eaten in midsummer, the latter not until toward the close of the season, or remaining only slightly damaged until then. In 1882 the leaves were eaten faster than they could be developed, and the insect continued abundant enough to prevent a second crop of foliage until in November, when it became too cold for the leaves and active insects to exist.

On these grounds the southeast half of each tree has suffered more than the northwest half. This peculiarity has been very strongly pronounced this year, 1883, on all the trees affected, and upon some exam-

ples far more markedly than upon others. This one-sidedness is especially apparent in the trees which were the most severely eaten. Some trees show the southeast side completely devoured, but the northwest side only half consumed and comparatively green. Such are average cases.

The inferences have been, that the shade, dampness, and coolness of the tree on the northwest side during the morning is too unhealthy for the favorable development of the larvæ or of the eggs deposited there; but whether this be true or not, the insect probably prefers to deposit chiefly in the middle of the forenoon, and on that part of the tree which is then warmest. This would give a greater number of the eggs at the outset on the southeast side, as observation seems to confirm, and since the young larvæ do not migrate to any noteworthy extent, the one-sidedness described would result, whether the northwest side were unhealthy or not. The former explanation is most probably the correct one, as we have noticed that the insect is less injurious during very wet summers.

Preferences of the Elm-beetles for certain Varieties and Species of Elms.—The American Slippery Elm does not occur in this grove, but only one native species, the common American Elm, *Ulmus americana*. This is practically free from the ravages of the beetle, on which account it may be preferred to the European species. It is tall, and has gracefully arched branches, making it as ornamental as any European kind, yet as a shade tree it does not equal the *U. montana* of the Old World. The latter has a broader, denser crown, but the attack on it is considerable, enough to leave the choice in favor of the American species.

U. montana seems the best European species grown here for shade, since the other foreign elms here cultivated are not dense enough. This applies to *U. campestris*, *U. suberosa*, *U. effusa*, and *U. parvifolia* (*siberica*). The last named is not attacked as much as the American. The young larvæ cannot develop on it, but die quite soon, without growing, and they gnaw the leaves very little. The other foreign species mentioned are seriously eaten; the severest attack being upon the *U. campestris*, the favorite food of this insect.

As early as June 25, in 1883, this species was completely eaten and brown in our grove, at which date the *U. montana* examples retained more than half their verdure; in some individuals nearly all; and the common American elm was perfectly green. The *U. campestris* is one of the poorest elms for shade, and its total abolishment throughout the entire country would probably lessen the assault on *U. montana* to a comparatively unobjectionable extent. This measure should be instituted against the pest, and for the sake of the other species of elms.

Effects of arsenical Poisons on Insect and Plant.—Species of elms are somewhat differently affected by the poison. When treated alike there is always manifest some difference in the susceptibility of different elms to the corrosive effects of the poison. Even individuals of the same

species or variety are differently impaired. As a rule, those which suit the insect best are injured most by the poison, and those which resist the insect most withstand the poison best. The latter have coarser foliage with a darker green color and more vigorous general growth; the former have more delicate foliage, lighter in color and weight, apparently less succulent.

Certain elms of the species *U. campestris* and other species which were overpoisoned, and shed most of their leaves in consequence, in the last of June, 1883, sent out a profuse new growth of leaves and twigs. The foliage fell gradually for three weeks, and this was somewhat promoted by the succeeding rains.

The larvæ move from place to place so seldom that if the leaves are imperfectly poisoned from the mixture being weakly diluted, or from its application only in large, scattered drops, which are much avoided by the larvæ, they are not killed off thoroughly for several days, and in all cases it requires considerable time to attain the full effect of the poison. This result appears on the plant and on the insect. After each rain the poison takes a new effect upon the plant and the pest, which indicates that the poison is absorbed more or is more active when wet, and that it acts by dehydrating thereafter. Where the tree is too strongly poisoned, each rain causes a new lot of leaves to become discolored by the poison or to fall. On some of the trees the discoloration appears in brown, dead blotches on the foliage, chiefly about the gnawed places and margins, while in other instances many of the leaves turn yellow, and others fall without change of color. The latter may not all drop from the effects of poison, but the coloration referred to is without doubt generally from the caustic action. The poison not only produces the local effects from contact action on the parts touched by it, but following this there appears a more general effect, manifest in that all the foliage appears to lose, to some extent, its freshness and vitality. This secondary influence is probably from poisoning of the sap in a moderate degree. When this is once observable, no leaf-eater thrives upon the foliage. Slight overpoisoning seems to have a tonic or invigorating effect on the tree.

Preventive Effects of the Poison.—In this grove the elms that were poisoned in 1882 were attacked in the spring of 1883 less severely than were those which were not poisoned the previous year. This would seem to imply that the insects deposit mostly on the trees nearest to where they develop, and are only partially migratory before ovipositing. The attack afterward became increased, probably by immigration and the new generation, so that later in the season the trees were mostly infested to the usual extent.

In the region of Washington *a preventive application of poison should be made* before the last of May or first of June, when the eggs are being deposited and before they hatch. This will prevent the worms from ever getting a start. By the preventive method the tree escapes two

kinds of injury; first, that directly from the eating by the insect; second, that which follows indirectly from the deleterious effects of the poison on the plant, for its caustic effect is much greater where the leaves have been so gnawed that the poison comes in contact with the sap.

Treatment with London purple.—Already early in June the insect appears plentiful. On June 7, 1882, it was at work on all the trees, and its clusters of eggs were numerous beneath the leaves. Some of the trees had half of the leaves considerably gnawed and perforated by larvæ of all sizes, and by the adults. At this date fifteen trees, constituting the south part of the grove, were treated.

Preparation of the Poison.—London purple (one-half pound), flour (3 quarts), and water (barrel, 40 gallons) were mixed, as follows: A large galvanized iron funnel of thirteen quarts capacity, and having a cross-septum of fine wire gauze, such as is used for sieves, also having vertical sides, and a rim to keep it from rocking on the barrel, was used. About three quarts of cheap flour were placed in the funnel and washed through the wire gauze by water poured in. The flour in passing through is finely divided, and will diffuse in the water without appearing in lumps. The flour is a suitable medium to make the poison adhesive. The London purple is then placed upon the gauze and washed in by the remainder of the water until the barrel is filled. In other tests the flour was mixed dry with the poison powder, and both were afterward washed through together with good results. It is thought that by mixing in this way less flour will suffice. Three-eighths of a pound of London purple to one barrel of water may be taken as a suitable percentage. Three-eighths of an ounce may be used as an equivalent in one bucketful of water. The amount of this poison was reduced to one-fourth of a pound to the barrel with good effect, but this seems to be the minimum quantity, and to be of value it must be applied in favorable weather and with unusual thoroughness. With one-half or three-fourths of a pound to the barrel, about the maximum strength allowable is attained, and this should be applied only as an extremely fine mist, without drenching the foliage.

Effects of the Mixture.—The flour seems to keep the poison from taking effect on the leaf, preventing to some extent the corrosive injury which otherwise obtains when the poison is coarsely sprinkled or too strong. It also renders the poison more permanent. On the leaves, especially on the under surfaces, the London purple and flour can be seen for several weeks after it has been applied, and the insect is not only destroyed, but is prevented from reappearing, at least for a long period. By poisoning again, a few weeks later, the insect is deterred with greater certainty for the entire season. By being careful to administer the poison before the insect has worked, and, above all, to diffuse the spray finely but not in large drops, no harm worth mention-

ing will accrue to the plant from the proportion of poison recommended. The new growth, that developed after the first poisoning, was protected by one-fourth of a pound to the barrel in 1882. From midsummer until autumn the unpoisoned half of the grove remainded denuded of foliage, while the poisoned half retained its verdure. The little damage then appearing in the protected part was mostly done before the first treatment. Eggs were laid abundantly throughout the season. Many of these seemed unhealthy and failed to develop, probably because they were poisoned. Many hatched, but the young larvæ soon died. The eggs were seldom deposited on the young leaves that were appearing after the poison was applied, but were attached to the developed leaves, and here the larvæ generally got the poison to prevent their attack upon the aftergrowth. Still the young leaves became perforated to some extent. The adults, which fly from tree to tree, appeared plentifully without much interruption throughout the season, and often several could be seen feeding on each tree. Possibly many of these may have become poisoned before depositing the eggs.

The efficiency of London purple being established, it will generally be preferred to other arsenicals, because of its cheapness, better diffusibility, visibility on the foliage, &c. As the effects of the poisons commonly do not appear decidedly for two or three days after their administration, the importance of the preventive method of poisoning in advance cannot be too strongly urged. As the effect is slow in appearing, impatient parties will be apt to repoison on the second or third day, and thus put on enough to hurt the plant when the effect does come. Much depends on dryness or wetness of the weather; but good effects may be expected by the third or fourth day.

London purple seems to injure the plant less than Paris green.

Treatment with Paris green.—In 1883 the Paris green was first applied on the 29th of May, at which date the eggs were extremely abundant and hatching rapidly on the leaves. Paris green, flour, and water were mixed by the means previously employed with London purple and already described. The mixture was applied to the north part of the same grove of elms. Thus far experience shows that the Paris green is effective against the insect, but that this poison injures the plant more than does the London purple.

Three-fourths of a pound of Paris green to a barrel (36 or 40 gallons) of water, with 3 quarts of flour, may be regarded as a poison mixture of medium or average strength for treating elms against these beetles, and the indications thus far are that the amount of Paris green should not be increased above one pound or be diminished much below one-half a pound in this mixture. To a bucketful of water three-fourths of an ounce of Paris green may be used. The action of this poison is slow but severe, and varies much with the weather. Thus far the results of tests have been varied so much by the weather and different modes of preparation and application that they will be repeated. When

used strong enough to cauterize the leaves the poisonous action upon the plant may be observed to continue for several weeks.

Mechanical Means of applying the Poison.—When many trees were to be sprayed a cart or wagon was employed to haul the poison in a large barrel provided with a stirrer, force-pump, skid, &c. The following brief account of the skid, mixer, barrel, and pump may be reproduced here from our Annual Report for 1882:

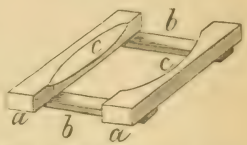

FIG. 2.—*Barrel rest or skid*; two coupling cleats, *b b*; two side rests *a a*; chamfered concave, *c c*.

The skid is a simple frame to hold the horizontal barrel from rolling, and consists of two pieces (Fig. 2 *a a*) of wood, about the length of the barrel, and in section about 3 by 4 inches, joined parallel, apart from each other, by two cleats, *b b*. The inner upper angles may be cut to match the curve of the barrel, as at *c c*. The barrel being placed upon this frame is next to be filled.

A good device for mixing the poison thoroughly with the water and for filling the barrel is shown in section in Fig. 3. It consists of a large funnel that will hold a bucketful, and has cylindrical sides, *g g*, that rest conformant on the barrel. In this is a gauze or finely perforated diaphragm, or septum, *d*, and a funnel base, *t t*, with its spout, *p*, inserted through the bung.

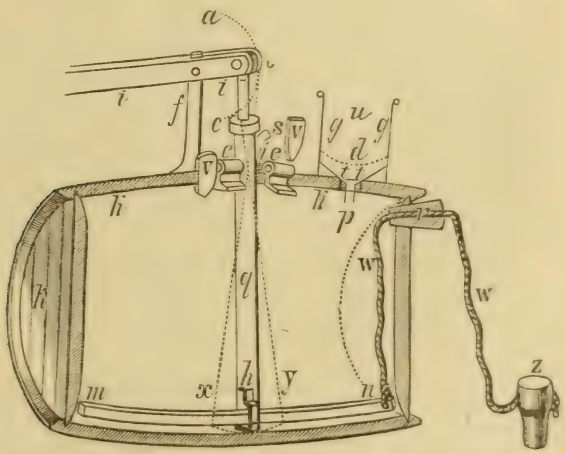

FIG. 3.—*Stirrer pump with barrel and mixer funnel in section*: funnel, *u*; its cylindrical sides, *g g*; funnel base, *t t*; spout, *p*; (in bung-hole, *k*), gauze septum, *d*; barrel, *k k*; trunnions, *i*; trunnion eyes, *e*; wedge, *v*; lever-fulcrum, *f*; pump lever, *i i*; swing of the lever head and piston top, *a b c*; cylinder packing cap, *c*; cylinder, *g*; its swing, *x y*; stirrer loop or eye, *h*; stirrer bar, *m n*; rope, *w w*; bung, *r z*.

By reference to Fig. 3, the barrel, *k*, will be seen in section, and some of its details, together with those of the pump and stirrer, may be noticed. The fulcrum, *f*, has a foot below, screwed to the barrel. Through its top is a pivot, *o*, on which tilts the pump-lever, *l*, which is similarly hinged at *b* to the top of the piston-rod, *t*. The pump-cylinder, *g*, is also hung upon trunnions, *i*, projecting into eyes. In this illustration the eyes, *e e*, have each a neck fitting in a slot cut through the stave, oppositely from the side of the bung-hole, and beneath the stave is a foot on the eye-piece. Its neck is so short that the eye is held down firmly against the top of the stave, while the foot is as tight against its under surface. The length of its eye-piece is a little less than the diameter of the bung-hole, into which it may be inserted to be

driver laterally into the slot. The slot is longer than the eye-piece, so the latter may be driven away from the bung-hole for a distance greater than the length of the trunnion pivot. Then the pump being inserted, until these pivots come opposite the eyes, the latter may be driven back as sockets over the pivots, which play in them when the pump is worked. To hold these eyes toward the pump and upon the trunnions a wedge, *r*, is driven in the slot beyond each eye-piece. Thus the pump is easily attached or removed, and its union with the barrel is strong and firm. Perchance it be desired that this pump-hole be bunged, the side slots may be wedged to make the barrel tight.

The parts of the pump being hung as described, the hinge, *b*, forms a toggle-joint, and in its action causes the pump to oscillate on its trunnions, its basal end swinging wider than its top, as indicated by the dotted line from *x* to *y*. Upon the extremity of this swinging end is a loop, *h*, through which is passed the stirrer-bar, *m n*, made to sweep back and forth in the lower side of the barrel, thus to agitate and mix the substances considerably during the operation of the pump, every stroke of the handle causing one or two strokes of the stirrer.

The method of inserting and extricating the stirrer-bar is as follows: It is raised with the pump until the end, *m*, comes opposite the bung-hole, *x*, through which the bar may be pulled out by the cord, *w*, which is attached to the end, *n*, and also preferably to the bungs *r* and *z*, as shown. Through the same hole the bar may be inserted. This stirring device is the simplest in construction and operation of any yet contrived. While working as it does with reference to the concavity of the barrel it is perfectly effective.

The pump is double-acting and very powerful, giving strong pressure to disperse the liquid far and finely, for, with the eddy-chamber nozzle used, the greater the pressure the finer is the liquid atomized. A block or other catch may be fixed on the side of the barrel to fit against the skid and prevent the barrel from rocking therein, as might otherwise happen when it is nearly empty if much power is applied. About one pailful of poisoned water was sprayed upon each tree. When only two or three trees were to be treated an Aquapult or other bucket-pump was used to force the poison from a bucket carried by hand. The Paris-green mixture needs to be almost constantly stirred, as this poison precipitates quickly; but with London purple the agitation is only occasionally necessary.

Connected with either pump is a long, flexible pipe, with its distal part stiff, and serving as a long handle whereby to hold its terminal nozzle beneath the branches or very high up at a comfortable distance from the person managing it. Parts of one form of this extension pipe are shown in Figs. 4 and 5.

To the pump spout is attached the long, 2-ply, flexile hose, *h h*, of $\frac{1}{4}$-inch caliber. Its considerable length, 12 feet or more, allows the nozzle to be carried about the tree without moving the pump. Beyond its flexile part the hose, *h*, passes through a bamboo pole, *b*, from which the septa have been burned out by a hot iron rod. At the distal end of the pole the hose terminates in a nozzle, *n* or *m*. When the nozzle is in its natural position, *m*, the spray, *z*, is thrown straight ahead, and this suits well for spraying very high branches, but for spraying the under surfaces of the lower parts of the tree it is necessary that the nozzle discharge laterally from the pipe, and this is accomplished with a noz-

zle having a direct discharge by bending it to one side. The nozzle, *n*, and spray, *s*, are directed laterally, and the nozzle, *n*, is maintained in this position by a metallic hook or eye, *v*, having a crooked stem inserted at the side of the hose in the end of the pole. Where the side spray is permanently desired, the metallic stem is inserted inside the hose and connected with the base of the nozzle, or the tubular stem of the nozzle is given the desired crook. For small trees the simpler extension pipe shown in Fig. 5 is satisfactory. The metallic tube, *t*, several feet in length, is used as the stiff part, *t*, connected with the hose, *h*. One longer metallic pipe, having telescopic sections made tight by outside segments of rubber tubing, has also been employed, and is a very desirable extension pipe. Where only low end-spraying is to be done, as upon small trees, &c., the eddy-chamber nozzle (Fig. 6) is set upon such a pipe, or upon its own stem, so as to discharge at right angles therefrom; but a diagonal position of the chamber, *n*, on its stem, *i*, throws the spray, *s*, at an intermediate angle between the right angle and a direct line, by which, without any readjustment, the spray, *s*, can be directed higher or lower, beneath the foliage or above. For general use, this kind of nozzle is the best. It consists of a shallow, circular, metal chamber (Fig. 6, *c*), soldered to a short piece of metal tubing, *a*, as an inlet. The inlet passage, *x*, penetrates the wall of the chamber tangentially, admitting the fluid eccentrically, and causing it to rotate rapidly in the chamber. The outlet consists of a small hole, *s*, drilled in the exact center of the face, *e*, of the chamber, and through this outlet the fluid is driven perpendicularly to the plane of rotation in the chamber, and converted into a very fine spray. For a full description of this nozzle the reader is referred to our report as Entomologist to the Department of Agriculture for the years 1881–'82, p. 162. With ordinary force-pump pressure the discharge-hole of the nozzle is about one sixteenth of an inch in diameter for misty sprays with particles invisibly small. Rather than use the larger, coarser sprays, which were usually employed in these tests, it is better to use the finest spray. The spray falling upon the extension pipe soon accumulates enough to flow down the pole and wet the hands. To prevent this a wrapping washer of leather or other flange

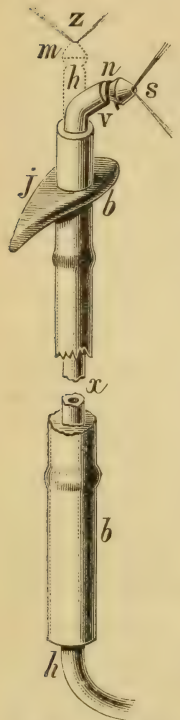

FIG. 4.—*Parts of hose-pole device for spraying trees*: bamboo pole, *b b*; drip washer, *j*; hose, *h x*; side hook, *v*; eddy chamber nozzle, *n m*; spray, *z s*.

FIG. 5.—*Metallic hand pipe with diagonal nozzle*: hose, *h*; metallic pipe, *t*; diagonal eddy chamber nozzle, *n*; its removable face, *i*; spray, *s*.

may surround the pole proximally from the spray, and the drip will drop off from its margin. Such an arrangement is indicated at *j* in Fig. 4.

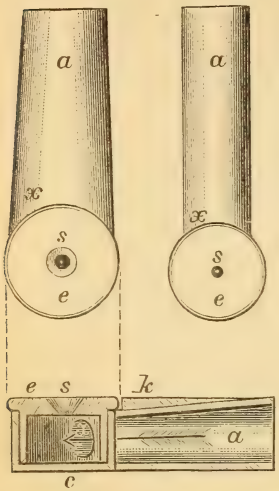

FIG. 6.—*Eddy-chamber nozzle*, natural size; face view and section.

While one person operates the pump, another, standing in the vehicle or upon the ground, directs the spray by the stiff part of the pipe. Thus the operator can not only spray higher and lower with convenience, but he can, to a great extent, move the spray from place to place without leaving his own position and without moving the vessel of poison with the pump.

The hose and bamboo combination was conceived of, and used as the lightest, long, stiff tube practicable for these purposes, and it has answered admirably. A similar pole, with a metallic tube in its interior, with a nozzle not producing the very fine mist desired, and lacking the side discharge, &c., was afterward learned of as being used in California. (See Agricultural Department Report, 1881-'82, p. 208.)

By the apparatus used, when everything is prepared, a tree can be sprayed quickly, and a large grove is treated in a short time. It is equally adapted for forestry use in general, and likewise available for poisoning on fruit trees, when not in fruit, while the shorter style of extension-pipe is convenient for underspraying all kinds of low plants.

THE BAG-WORM.

(*Thyridopteryx ephemeræformis* Haw.)

Although this species was not particularly destructive to our shade-trees in 1886, and in numbers greatly inferior to the Fall Web-worm and the Tussock-moth, yet in 1879 it was much more formidable, and at irregular intervals becomes a great pest where not properly dealt with, especially in more southern States. For the past two or three years it has been on the increase in special localities in Washington, and should be carefully looked after.

HABITS AND NATURAL HISTORY.

The Eggs.—During winter time the dependent sacs or bags of this species may be seen hanging on the twigs of almost every kind of tree. If they happen to be on coniferous trees, and they are usually more abundant on these than on deciduous trees, they are not infrequently mistaken for the cones. In reality they are the coverings spun by our worm, and they serve not only as a protection to it, but also to the eggs. Upon cutting open the larger of these bags in winter time they will be found to contain the shell of a chrysalis (technically called the puparium), which is filled with numerous small yellow eggs (Fig. 7 *e*). Each of these is a little over 1 millimeter in length, obovate in form, and surrounded by a delicate, fawn-colored, silky down. In this condition the eggs remain from fall throughout the winter and early spring.

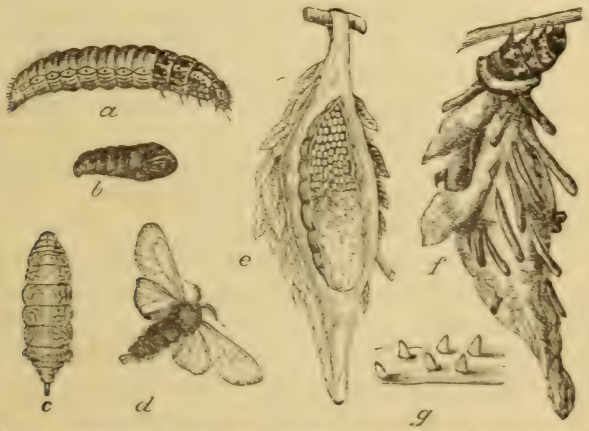

FIG. 7.—*Thyridopteryx ephemeræformis*: *a*, larva; *b*, male chrysalis; *c*, female moth; *d*, male moth; *e*, bag and puparium cut open to show eggs; *f*, full grown larva with bag; *g*, young larvæ with their conical upright coverings; all natural size.

The Larva and its Bag.—About the middle of May in this latitude the eggs hatch into small but active larvæ, which at once commence to con-

struct a portable case or bag in which to live. The way in which this bag is prepared is curious (Fig. 8). The young larva crawls on a leaf, and

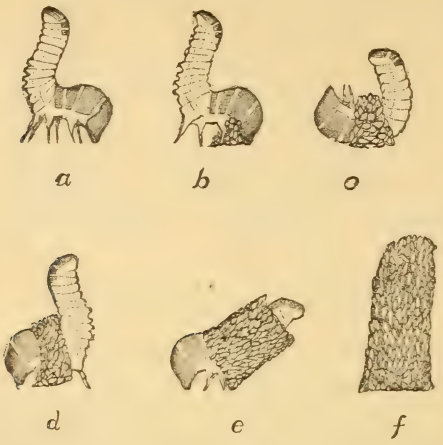

FIG. 8.—*Thyridopteryx ephemeræformis.* How the young larva prepares its bag.

gnawing little bits from the surface, fastens these together with fine silk, produces a narrow, elongate band, which is then fastened at both ends onto the surface of the leaf by silky threads. Having secured itself from falling down by some threads, it now straddles this band and, bending its head downward (Fig. 8 *b*), makes a dive under it, turns a complete somersault and lies on its back, held down by the band (Fig. 8 *c*). By a quick turning movement the larva regains its feet, the band now extending across its neck (Fig. 8 *d*). It then adds to the band at each end until the two ends meet, and they are then fastened together so as to form a kind of narrow collar which encircles the neck of the worm. Far from resting, it now busies itself by adding row after row to the anterior or lower end of the collar, which thus rapidly grows in girth and is pushed further and further over the maker (Fig. 8 *e*). The inside of this bag is now carefully lined with an additional layer of silk, and the larva now marches off, carrying the bag in an upright position (Fig. 7 *g* and Fig. 8 *f*). When in motion or when feeding, the head and thoracic segments protrude from the lower end of the bag, the rest of the body being bent upward and held in this position by the bag. As the worms grow they continue to increase the bags from the lower end and they gradually begin to use larger pieces of leaves, or bits of twigs or any other small objects for ornamenting the outside. Thus the bags will differ according to the different kind of tree or shrub upon which the larva happens to feed; those found on coniferous trees being ornamented with the filiform pine leaves, usually arranged lengthwise on the bag, while those on the various deciduous trees are more or less densely and irregularly covered with bits of leaves interspersed with

pieces of twigs. When kept in captivity the worms are very fond of using bits of cork, straw, or paper, if such are offered to them. When the bags, with the growth of the larva, get large and heavy, they are no longer carried, but allowed to hang down (Fig. 7 *f*). The worms undergo four molts, and at each of these periods they close up the mouth of their bags to remain within until they have cast their skin and recovered from this effort. The old skin, as well as the excrement, is pushed out through a passage which is kept open by the worms at the extremity of the bag.

The young larva is of a nearly uniform brown color, but when more full-grown that portion of the body which is covered by the bag is soft, of light-brown color and reddish on the sides, while the head and thoracic joints are horny and mottled with dark-brown and white (Fig. 7 *a*). The numerous hooks with which the small, fleshy prolegs on the middle and posterior part of the body are furnished, enable the worm to firmly cling to the silken lining of the bag, so that it can with difficulty be pulled out.

The bag of the full-grown worm (Fig. 7 *f*) is elongate-oval in shape, its outlines being more or less irregular on account of the irregularities in the ornamentation above described. The silk itself is extremely tough and with difficulty pulled asunder.

The larvæ are poor travelers during growth, and though, when in great numbers, they must often wander from one branch to another, they rarely leave the tree upon which they were born unless compelled to do so by hunger through the defoliation of the tree. When full-grown, however, they develop a greater activity, especially when very numerous, and, letting themselves down by a fine silken thread, travel fast enough across sidewalks or streets and often for a considerable distance until they reach another tree, which they ascend. This migratory desire is instinctive; for should the worms remain on the same tree they would become so numerous as to necessarily perish for want of food.

Pupation.—The bags of the worms which are to produce male moths attain rather more than an inch in length, while those which produce females attain nearly double this size. When ready to transform, the larva firmly secures the anterior end of the bags to a twig or branch, and instinct leads it to reject for this purpose any deciduous leaf or leaf-stem with which it would be blown down by the winds. The inside of the bag is then strengthened with an additional lining of silk, and the change to chrysalis is made with their heads always downward. The chrysalis is of a dark-brown color, that of the male (Fig. 7 *b*) being only half the size of that of the female (Fig. 7 *e* and Fig. 9 *a*).

The Imago or perfect Insect.—After a lapse of about three weeks from pupation a still greater difference between the two sexes becomes apparent. The male chrysalis works its way to the lower end of the bag and half way out of the opening at the extremity. Then its skin bursts

and the imago appears as a winged moth with a black, hairy body and glassy wings (Fig. 7 *d*). It is swift of flight, and, owing to its small size and transparent wings, is rarely observed in nature. The life-duration of this sex is also very short. The female imago is naked (save a ring of pubescence near the end of the body of yellowish-white color), and entirely destitute of legs and wings (Fig. 7 *c*, and Fig. 9 *b*). She pushes her way partly out of the chrysalis, her head reaching to the lower end of the bag, where, without leaving the same, she awaits the approach of the male. The manner in which the chrysalis shell is elongated and reaches to the end of the bag is shown in Fig. 9 *a*, and an enlarged side view of the female, showing the details of structure, is shown at *b*, in the same figure. The extensility of the male genitalia, which permits him to reach the female within her bag, is set forth in the accompanying Fig. 10, where the parts are shown at rest, *c* and *d*, and in action, *b*. Fertilization being accomplished, the female works her way back within the chrysalis skin and fills it with eggs, receding as she does so toward the lower end of the bag, where, having completed the work of oviposition, she forces, with a last effort, her shrunken body out of the opening, drops exhausted to the ground, and perishes. When the female has withdrawn the slit at the head of the puparium and the elastic opening of the bag close again, and the eggs thus remain securely protected till they are ready to hatch the ensuing spring.

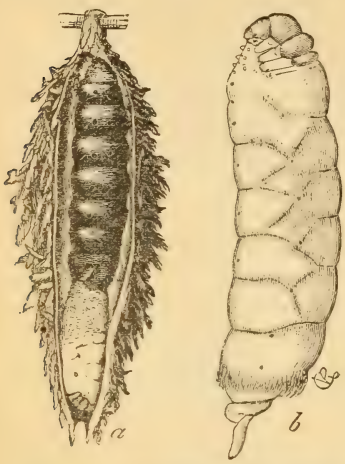

FIG. 9.—*Thyridopteryx ephemeræformis*: *a*, Follicle cut open to show the manner in which the female works from her puparium and reaches the end of the bag, natural size; *b*, female extracted from her case, enlarged.

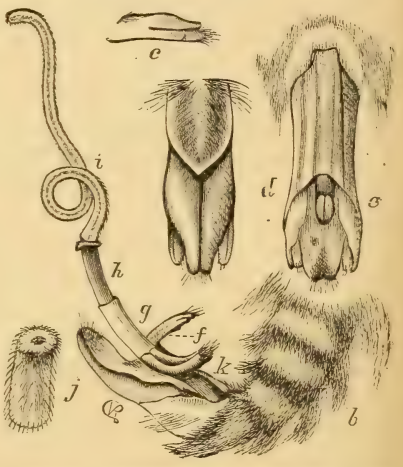

FIG. 10.—*Thyridopteryx ephemeræformis*: *b*, The end of male abdomen from the side, showing genitalia extended; *c*, genitalia in repose ventral view; *d*, do, dorsal view enlarged.

GEOGRAPHICAL DISTRIBUTION.

The Bag-worm occurs most frequently in the more southern portion of the Middle States and in the Southern States, but seems to be absent from the Peninsula of Florida. Within these limits it extends from the Atlantic to Texas, and reaches the less-timbered region west of the Mississippi. Northward

it is occasionally found in New York, and even Massachusetts, but so rarely and locally restricted that neither Dr. Harris nor Dr. Fitch mention it in their publications on economic entomology. Wherever it occurs it prefers the gardens and parks within or near the cities, being much less abundant in the woods remote from cities, and this dependence upon the vicinity of human civilization is more marked in this species than in any of the others here treated of.

FOOD PLANTS.

The Bag-worm is known to feed on a large number of trees and shrubs, but has a predilection for certain kinds of coniferous trees, notably the Red Cedar and Arbor Vitæ, and as these evergreens are much less able to stand the loss of their foliage than the deciduous trees, the worms are much more dangerous to the former than to the latter. The Hard Maples are, as a rule, avoided by the worms, and it is also quite noticeable that they are not particularly fond of oak leaves and those of the Paulonias. The Ailanthus trees are also generally exempt from their attacks, either on account of the unpleasant taste of the leaves, or perhaps on account of the compound nature of the leaves, the worms fastening their bags to the leaf stems which fall to the ground in Fall. With these exceptions,* the worms, when sufficiently numerous, do great damage to most other kinds of trees used in our cities as shade and park trees.

ENEMIES.

The Bag-worm is so well protected in all its stages that no insectivorous bird nor predaceous insect is known to attack it. In spite of

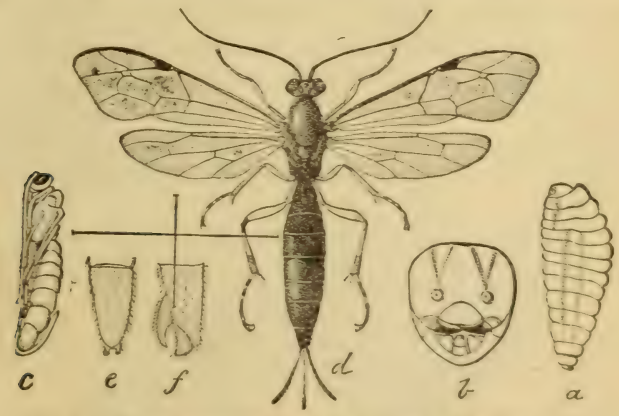

FIG. 11.—*Pimpla conquisitor*: *a*, larva; *b*, head of do. from front; *c*, pupa; *d*, adult female (hair line indicating natural size); *e*, end of male abdomen from above; *f*, same from the side—all enlarged.

the absence of predaceous enemies, the Bag-worm suffers from the attacks of at least six true parasites, while two others, which may be

* The China trees of our Southern cities are entirely exempt from the worms.

primary but are probably secondary, are reared from the bags. Three of these are Ichneumonids, viz: (1) *Pimpla conquisitor* Say (Fig. 11); (2) *Pimpla inquisitor* Say, and (3) *Hemiteles thyridopterigis* Riley (Fig. 12).

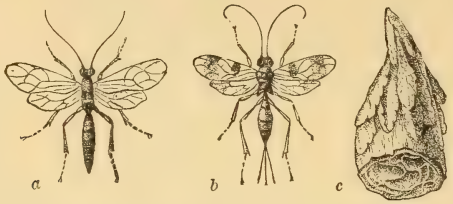

FIG. 12.—*Hemiteles thyridopterigis: a*, male; *b*, female; *c*, sack of bag-worm cut open, showing cocoons of parasite, natural size.

Of these, the last-named is most abundantly bred, and we have always considered it as the most important parasite of the Bag-worm. The past season, however, we have ascertained that three species of the genus *Hemiteles*, viz: *H. utilis*, and two undescribed species, are unquestionably secondary parasites, and this renders it quite likely that *H. thyridopterigis* may also be secondary, or, in other words, a parasite of one of the true parasites of the Bag-worm. It is a question, however, which only the most careful study, with abundant material, can decide, as the law of unity of habit in the same genus finds many exceptions in insect life. The other parasites are as follows: (4) *Chalcis ovata* Say. This parasite is a very general feeder on Lepidopterous larvæ, and we have bred it from seven widely different species. (5) *Spilochalcis mariæ* (Riley). This species, while parasitic on Thyridopteryx, is more partial to the large silk-spinning caterpillars, as we have reared it from the cocoons of all of our large native Silk-worms. (6) *Pteromalus* sp. This undescribed Chalcid is found very abundantly in the Bags, but may be a secondary parasite. (7) *Dinocarsis thyridopterygis* Ashmead. This parasite was bred from the Bags in Florida by Mr. William H. Ashmead, who believes it to be parasitic on the eggs. (8) *Tachina* sp. We have bred a large bluish Tachinid from the Bags. Its eggs are commonly attached to the Bags externally, near the neck, and the young larvæ, on hatching, work their way into the case. They frequently fail, however, to reach the Bag-worm.

THE WHITE-MARKED TUSSOCK-MOTH.

(*Orgyia leucostigma* Smith & Abbot.)

HABITS AND NATURAL HISTORY.

The Eggs.—During the month of June, and more especially late in fall and throughout the winter, glistening white objects may be seen on the trunks and the larger branches of trees, or in the corners of the fences near by, or on bunches of dead leaves hanging on the tree (see Fig. 13 *a*). Upon examination these masses will be found to be glued onto a cocoon of dirty gray color, and to consist of numerous perfectly round, cream-white eggs, which are partly covered by a glistening white froth

Fig. 13.—*Orgyia leucostigma*: *a*, female on cocoon; *b*, larva; *c*, female pupa; *d*, male pupa.

or spittle-like matter. In one of these egg-masses which we received from Kansas we have counted as many as 786 eggs, while from another mass we obtained upward of 400 young caterpillars.

Development and Characters of the Larva.—In the latitude of Saint Louis, Mo., and Washington the eggs begin to hatch about the middle of May, and the newly-born caterpillar, not quite 3 millimeters in length, is of dull whitish-gray color, with the under side paler, the upper side being covered with rather long hairs and tufts of a dark-brown color. In two days from hatching small orange spots begin to appear along

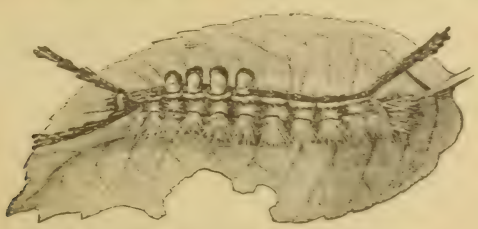

Fig. 14.—*Orgyia leucostigma*: female caterpillar.

the back, and on the seventh day the first molt takes place, to be followed at intervals of six days each by the second and third molts. The changes that take place during this time in the appearance of the caterpillar are remarkable, and after the third molt it is a beautiful ob-

ject and of striking appearance (Fig. 14). The head and two little elevated spots situated on joints 9 and 10, are bright vermilion-red; the back is velvety black with two bright yellow subdorsal lines, and another yellow line each side along the lower sides. The whole body is thinly clothed with long pale yellow hairs, originating from small wart-like elevations. Four cream-colored or white dense brushes of hair are in a row on the middle of the fourth, fifth, sixth, and seventh dorsal joints, while from each side of the head arises a long plume-like tuft of black hair projecting forward and outward. A similar plume projects upwards from the last dorsal joint. The hairs composing these plumes are coarse, barbed, knobbed, and arranged in sets of unequal length, thus giving the plumes a turbinate appearance.

Habits of the Larva.—The young caterpillars scatter all over the tree soon after hatching. When disturbed they make free use of a fine silken thread which they spin, and by which they let themselves down. The full-grown larvæ are often seen to change quarters and travel from one branch to another, or from one tree to another. Their rather quiet way of moving contrasts strongly with the nervous movements of the Fall Web-worm.

A new Form of Orgyia Attack.—In the first edition we omitted to make mention of a most interesting account of a new form of Orgyia attack which had just been published at that time by Mr. Lintner in his second report as State entomologist of New York. We can not now do bett r than to insert his account of this peculiar injury in his own words. It is an interesting instance of a new habit having been locally acquired, and, so far as we have been able to ascertain, it has been observed nowhere else—

"In the summer of 1883, contemporaneously with the first appearance of the Orgyia attack upon the foliage, between the 10th and the 15th of June, the sidewalks, streets, and public parks in Albany, wherever the white elm (*Ulmus Americanus*) was growing, were observed to be sprinkled with newly-fallen leaves. They continued to drop in increasing number until toward the close of the month, when, in many places where they had been permitted to lie undisturbed, they completely covered the walks or ground.

"Upon taking some of them up for examination, they were found to be attached to the tips of the twigs and to comprise nearly all of the new growth of the season. The pieces were from 2 to 3 inches in length, each bearing from four to ten fresh uninjured leaves. It was evident that they were not being broken off by unusually high winds, for even in the absence of winds each day continued to add to their number and to increase the abundance of the fall.

"Making critical observation for the discovery, if possible, of the cause of so unusual a phenomenon, it was noticed that from above the point at which the tip had been broken the bark was entirely removed for an extent averaging one-tenth of an inch. The manner of its removal showed it to have been eaten by an insect. The suggestion was made to me that it was the work of some small insect of similar habits to those of the twig girdler, *Oncideres cingulatus* (Say), but the closest examination failed to show either scar or egg within the tip.

"From the character of the injury, together with the abundant presence of the caterpillar upon the trees at the time, and of no other observed depredator, I believed that it was the work of the Orgyia. If so, it was of especial interest, as showing a new habit developed, for this form of attack had never been recorded of the insect. To verify the belief, after ascending some trees and examining branches within reach from windows, I went upon a house-top, where the limbs of a large elm projecting over the roof gave an excellent opportunity for examination. The larvæ were abundant upon the tree; the flat roof was strewn over and heaped in corners with the broken-off tips; very many girdled tips still held their place on the tree, and after careful search Orgyia larvæ were discovered in the act of eating the bark at the girdled points. From later observations it appeared that the girdling had at this time nearly ceased.

"The following explanation of the cause of the falling of the girdled tips seems a rational one. Upon the eating away of the bark by the Orgyia caterpillar, the wood rapidly dried from its exposure to the air and a rest of circulation, and soon became so brittle that from a moderate swaying of the branches the weight of a half dozen or more of large succulent leaves would occasion the breaking off of the slender twig—often not exceeding in its dried state the diameter of an ordinary pin.

"For the occurrence at this time of this novel form of Orgyia attack, I can only offer the following as a plausible explanation: The spring had been remarkably cold, and as a consequence the development of the foliage had been delayed to quite beyond the ordinary time. The sudden advent of warm weather caused a corresponding sudden start in vegetation, followed by a vigorous growth, and the young tips of the elm would, as the result, be unusually tender. The particular feeding ground of many of the lepidopterous larvæ is known to be selected only after repeated tastings and rejections of such portions of their food-plant as they traverse and a final acceptance of that most agreeable to them. By a process like this the Orgyia may have made the discovery that just at the commencement of the new growth, as the result of the seasonal conditions above mentioned, there was concentrated in the tender bark nutriment far more acceptable to it than that offered in the leaves, upon which alone it had hitherto been accustomed to feed. As the bark hardened with the advancing season it would cease to be desirable for food. * * *

"On my return to Albany for a few days, on the 21st of July, most of the tips then falling and many of those upon the ground presented a new feature. The breaking, instead of being at the base of the girdling, just above the commencement of the new growth, was, in these, at the preceding node, covering the growth of the former year. As a rule, the twigs showed a greater diameter at their decorticated portion, compared with those of the earlier fall, and the leaves attached to them had been all more or less eaten by the Orgyia. Their greater strength had permitted them to remain longer upon the tree, and until the death of the preceding internode, which soon followed the arrest of the circulation—its starvation ensuing—it being unprovided with leaves through which a circulation could still be maintained. When dead, a slight movement of the branch by the wind, or even the weight of the terminal leaves, would be sufficient to disconnect it at its lower and weaker node. In a few instances, where the girdling had been at a little distance above the node marking the commencement of the present year's growth, the separation had been at this point, while others separated in this

manner, instead of the narrow girdling band, had had the bark irregularly removed for the extent of an inch or more. All these later falling twigs showed the interval that had elapsed between the injury and the fall, in that the roughened edges of the bark left by the gnawing had healed over with the peculiar roughened and rounded enlargement following the deposit of the reparative material under such conditions. Some of the twigs gathered gave excellent illustration of the ascent of the sap through the outer wood, and its return, after assimilation in the leaves, through the inner bark. In one instance, where the leaves were unusually large, the descending sap, arrested at the girdled point, had built up structure in the tip until its diameter was more than double that of the starved internode below, while the immediate point of the arrest was quite enlarged from the material there deposited.

"This peculiar attack did not extend to the other principal food-plants of the Orgyia, as the horse-chestnut, maple, apple and plum, nor would it be expected to occur in connection with growth and structure so different from that of the elm."

Pupation.—Six days after the third molt a portion of the larvæ spin up; all these produce male moths. The female caterpillars, which up to this time have been undistinguishable from the male caterpillars, undergo a fourth (and, as it appears from more recent experience, in some instances even a fifth) molt and acquire twice the size of the male caterpillar. This last, when full grown, measures about 20 millimeters in length. The cocoon spun by the male caterpillar is of whitish or yellowish color and sufficiently thin to show the insect within. It consists of two layers, the hairs of the tufts and brushes of the caterpillar being interwoven with the outer layer. The female cocoon is correspondingly larger, of gray color, and much more solid and denser than the male cocoon. The male chrysalis (Fig. 13 *d*), which is soon formed within the cocoon, is of brownish color, sometimes whitish on the ventral side, and covered on the back and sides with fine white hairs. The female chrysalis (Fig. 13 *c*) is much larger than the male, and otherwise differs, especially in lacking the wing-sheaths and in having on the three first segments after the head transverse, flattened protuberances composed of scales, which are much less visible in the male. The duration of the pupa state is less than a fortnight.

The Imago.—The male (Fig. 15) is a winged moth with feathery antennæ and very hairy fore legs. The general color is ashy-gray, the front wings being crossed by undulated bands of darker shade, with two black markings on the outer edge near the tip and a white spot on the inner edge also near the tip. He may frequently be seen sitting on the trunks of trees or on the shady side of houses, etc., as he rests during the day, and flies only after dusk, often being attracted by light. The female (Fig. 13 *a*) is totally different from the male in appearance and resembles a hairy worm rather than a moth, since she possesses the merest rudiments of wings. She is of a pale gray color, the antennæ being short and not feathered, the legs

FIG. 15.—*Orgyia leucostigma*: male.

rather slender and not covered with long hairs. She has consequently no power of flight, and is barely able to walk. After working her way out of the chrysalis and cocoon she takes her place on the outside of the latter and patiently awaits the approach of the male. Here she also deposits and protects her eggs in the manner already mentioned, after which she drops exhausted to the ground and perishes. The white mass covering the eggs is at first viscous, but soon dries, becoming brittle, and is impervious to water.

Hibernation.—The species hibernates normally in the egg state, but occasionally a living chrysalis may be found in winter time. On January 30, 1874, we received from Mr. Hunter Nicholson, from Knoxville, Tenn., a newly-hatched female, and this had, no doubt, prematurely issued from a hibernating chrysalis. This is, however, quite exceptional, and the different climatic conditions to which the species is subjected in its wide distribution do not seem to alter the normal mode of hibernation.

Number of Annual Generations.—In the latitude of Washington the species is two-brooded, the imagos of the first generation appearing in the first part of June, those of the second generation in September and October. On several occasions we have found, however, that a portion of the caterpillars from one and the same batch of eggs would be feeding while the rest had already transformed to imagos. The result of this retardation and irregularity in development is that caterpillars may be found continuously throughout the season from June till October, and that there is, consequently, no distinct dividing line between the two generations. In the more northern States the species is single-brooded, the caterpillars appearing in the months of July and August.

FOOD PLANTS.

This caterpillar has most often been referred to by writers on economic entomology as injurious to fruit trees, such as Plum, Pear, and more particularly the Apple; but it also attacks a great many shade trees, and has been for many years particularly injurious to the elms and the soft or silver maples in some of our larger New England cities. It has also a predilection for old or large trees.

NATURAL ENEMIES AND PARASITES.

The fact that the caterpillar makes no effort to conceal itself shows that it enjoys immunity from enemies, and notably from birds. In fact, the American Yellow-billed Cuckoo, the Baltimore Oriole, and the Robin are the only birds which have been observed to feed upon the larvæ. Predaceous insects are also not particularly fond of this hairy caterpillar, the well known Wheel-bug (*Prionidus cristatus*, see Fig. 16) and a few other Soldier-bugs being the only species which occasionally suck its

juices. Nocturnal birds, and especially bats, will, no doubt, devour many of the male moths flying about after dusk, but the destruction of a portion of the males has no appreciable influence on the decrease of

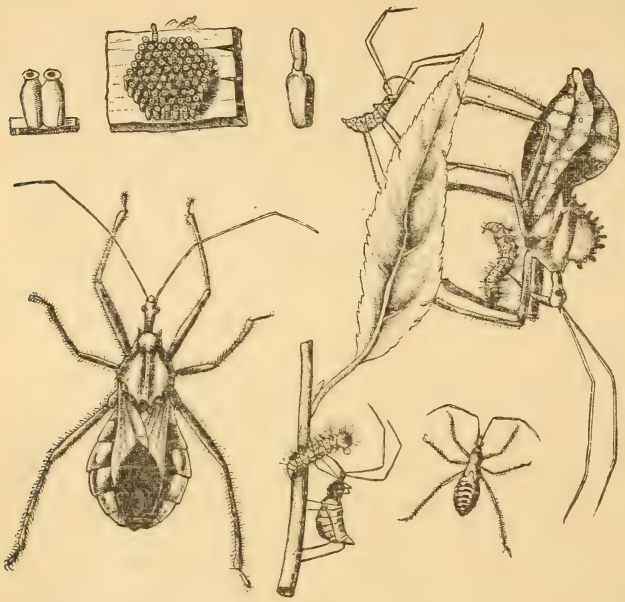

Fig. 16.—*Prionidus cristatus:* eggs, larvæ, and full-grown specimens.

the worms of the next generation. The egg-masses appear to be effectually protected by the froth-like covering, as neither bird nor predaceous insect has been observed to destroy them.

While the list of enemies that devour the species is thus small, that of the parasites is fortunately quite large, and it is due to their influence that the caterpillars are not permanently injurious. There are several true parasites of this insect. Fitch described one species which he bred in considerable numbers from the larva, as *Trichogramma? orgyiæ*, but a perusal of his account indicates plainly that this parasite is an *Eulophus*. He also described a closely-related insect as *Trichogramma? fraterna* and gave it as a very probable parasite of *Orgyia*. There is, however, not the slightest evidence of such parasitism, and this insect must in future be excluded from the list of parasites of the Orgyia larvæ. We have reared from this insect *Pimpla inquisitor*, and an undetermined Tachinid fly, and have had from the larva the cocoons of a Microgaster which has not been reared to the imago. We have also bred a true egg-parasite of the genus *Telenomus*, two distinct species of the genus *Pteromalus* from the larvæ, and Mr. Lintner has sent us a specimen of a species of *Tetrastichus* which is probably parasitic upon one of the *Pteromali*. Further characterization of these species we defer to another occasion.

GEOGRAPHICAL DISTRIBUTION.

This species is widely distributed in North America east of the more timberless regions of the West, extending northward as far as Canada and southward well into the Southern States. It is most abundant in the Middle and New England States, but it is a noticeable fact that wherever it occurs it is more frequent within our cities, or in gardens and orchards near by, than in the woods remote from human habitation.

THE FALL WEB-WORM.

(*Hyphantria cunea*, Drury.)

"This insect has from time to time attracted general attention by its great injury to both fruit and shade trees. Many authors have written about it, and consequently it has received quite a number of different names. The popular name 'Fall Web-worm,' first given to it by Harris, in his 'Insects injurious to Vegetation,' is sufficiently appropriate as indicating the season when the webs are most numerous. The term is, however, most expressive for the New England and other Northern States, where the insect is single-brooded, appearing there during August and September, while in more southern regions it is double-brooded. In our Third Missouri Report we have first called attention to its double-broodedness at Saint Louis, and we find that it is invariably two-brooded at Baltimore and Washington. Except in seasons of extreme increase, however, the first brood does no widespread damage, while the fall brood nearly always attracts attention.

"We have decided to call attention to this insect somewhat in detail in this report, because of its exceptional prevalence and injury in the Atlantic States during the year 1886, and because it became a public nuisance in the city of Washington, and the District Commissioners have formally requested information from us on the subject."

NATURAL HISTORY.

Limitation of Broods.—"At Washington we may say in general that the first brood appears soon after the leaves have fully developed, and numerous webs can be found about the first of June, while the second brood appears from the middle of July on through August and September. In Massachusects and other Northern States the first moths issue in June and July; the caterpillars hatch from the last of June until the middle of August, reach full growth and wander about seeking places for transformation from the end of August to the end of September.

"The species invariably hibernates in the chrysalis state within its cocoon, and the issuing of the first brood of moths is, as a consequence, tolerably regular as to time, *i. e.*, they will be found issuing and flying slowly about during the evening, and more particularly at night, during the whole month of May, the bulk of them early or late in the month, according as the season may be early or late. They couple and oviposit

very soon after issuing, and in ordinary seasons we may safely count on the bulk of the eggs being laid by the end of May. During the month of June the moths become scarcer and the bulk of them have perished by the middle of that month, while the webs of the caterpillars become more and more conspicuous. The second brood of moths begins to appear in July, and its occurrence extends over a longer period than is the case with the first or spring brood. The second brood of caterpillars may be found from the end of July to the end of September, hatching most extensively, however, about the first of August.

"In Massachusetts and other Northern States the first moths issue in June and July; the caterpillars hatch from the last of June until the middle of August, reach full growth and wander about seeking places for transformation from the end of August to the end of September.

"The following general remarks upon the different stages refer to Washington and localities where the same conditions hold:

The Eggs (Fig. 17, *b*).—"The female moth deposits her eggs in a cluster on a leaf, sometimes upon the upper and sometimes on the lower side, usually near the end of a branch. Each cluster consists of a great many eggs, which are deposited close together and in regular rows, if the surface of the leaf permits it. In three instances those deposited by a single female were counted. The result was 394, 427, and 502, or on an average 441 eggs. But in addition to such large clusters, each female will deposit eggs in smaller and less regular patches, so that at least 500 eggs may be considered as the real number produced by a single individual. The egg, measuring 0.4 millimeters, is of a bright golden-yellow color, quite globular, and ornamented by numerous regular pits, which give it under a magnifying lens the appearance of a beautiful golden thimble. As the eggs approach the time of hatching this color disappears and gives place to a dull leaden hue.

FIG. 17.—*Hyphantria cunea*: *a*, moth in position on leaf laying eggs, side view; *b*, eggs enlarged.

"The interval between the time of depositing and hatching of the eggs for the first brood varies considerably, and the latter may be greatly retarded by inclement weather. Usually, however, not more than ten days are consumed in maturing the embryo within. The eggs of the summer brood seldom require more than one week to hatch.

"Without check the offspring of one female moth might in a single season (assuming one-half of her progeny to be female and barring all checks) number 125,000 caterpillars in early fall—enough to ruin the shade-trees of many a fine street.

The Larva (Fig. 18, *a*, *b*, and *c*).—"The caterpillars just born are pale yellow, with two rows of black marks along the body, a black head, and with quite sparse hairs. When full grown they generally appear pale yellowish or greenish, with a broad dusky stripe along the back and a yellow stripe along the sides; they are covered with whitish hairs, which spring from black and orange-yellow warts. The caterpillar is,

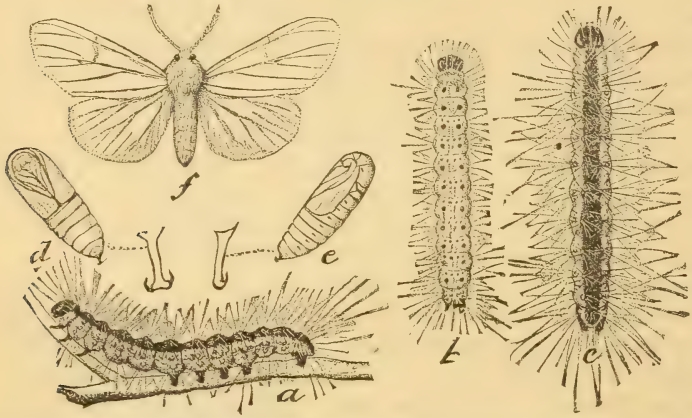

FIG. 18.—*Hyphantria cunea*: *a*, dark larva, seen from side; *b*, light larva from above; *c*, dark larva from above; *d*, pupa from below; *e*, pupa from side; *f*, moth.

however, very variable both as to depth of coloring and as to markings. Close observations have failed to show that different food produces changes in the coloration; in fact, nearly all the various color varieties may be found upon the same tree. The fall generation is, however, on the whole, darker with browner hairs than the spring generation.

"As soon as the young caterpillars hatch they immediately go to work to spin a small silken web for themselves, which by their united efforts soon grows large enough to be noticed upon the trees. Under this protecting shelter they feed in company, at first devouring only the green upper portions of the leaf and leaving the veins and lower skin unmolested. As they increase in size they enlarge their web by connecting it with the adjoining leaves and twigs; thus as they gradually work downwards their web becomes quite bulky, and, as it is filled with brown and skeletonized leaves and other discolored matter, as well as with their old skins, it becomes quite an unpleasant feature in our public thoroughfares and parks. The caterpillars always feed underneath these webs; but as soon as they approach maturity, which requires about one month, they commence to scatter about, searching for suitable places in which to spin their cocoons. If very numerous upon the same tree the food-supply gives out, and they are forced by hunger to leave their sheltering homes before the usual time.

"When the young caterpillars are forced to leave their webs they do not drop suddenly to the ground, but suspend themselves by a fine silken thread, by means of which they easily recover the tree. Grown caterpillars, which measure 1.11 inches in length, do not spin such a thread. Both old and young ones drop themselves to the ground without spinning when disturbed or sorely pressed by hunger.

Pupa and Cocoon.—"Favorite recesses selected for pupation are the crevices in bark and similar shelters above ground; in some cases even the empty cocoons of other moths.* The angles of tree-boxes, the rubbish collected around the base of trees and other like shelter are employed for this purpose, while the second brood prefer to bury themselves just under the surface of the ground, provided that the earth be soft enough for that purpose. The cocoon itself is thin and almost transparent, and is composed of a slight web of silk intermixed with a few hairs, or mixed with sand if made in the soil.

"The pupa (Fig. 18, *d* and *e*) is of a very dark-brown color, smooth and polished, and faintly punctate; it is characterized by a swelling or bulging about the middle. It is 0.60 inch long and 0.23 inch broad in the middle of its body, or where it bulges a little all round.

The Moth (Fig. 18, *b*).—"The moths vary greatly, both in size and coloration. They have, in consequence of such variation, received

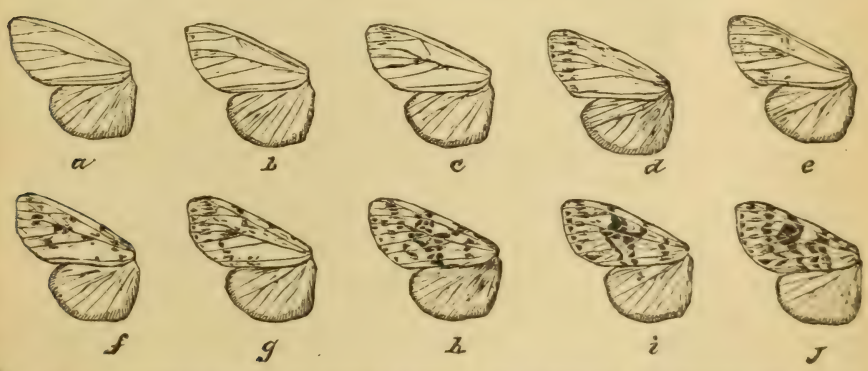

FIG. 19.—*Hyphantria cunea*: *a–j*, wings of a series of moths, showing the variations from the pure white form to one profusely dotted with black and brown.

many names, such as *cunea* Drury, *textor* Harr., *punctata* Fitch, *punctatissima* Smith (Fig. 19). But there is no doubt, as proven from frequent breeding of specimens, that all these names apply to the very same insect, or at most to slight varieties, and that Drury's name *cunea*, having priority, must be used for the species.

"The most frequent form observed in the vicinity of Washington is white, with a very slight fulvous shade; it has immaculate wings,

* We have known the substantial cocoon of *Cerura* to be used for this purpose.

tawny-yellow front thighs, and blackish feet; in some specimens the tawny thighs have a large black spot, while the shanks on the upper surface are rufous. In many all the thighs are tawny yellow, while in others they have scarcely any color. Some specimens (often reared from the same lot of larvæ) have two tolerably distinct spots on each front wing—one at base of fork on the costal nerve and one just within the second furcation of the median nerve. Other specimens, again, have their wings spotted all over, and approach the form *punctatissima*, described as the "Many-spotted Ermine-moth" of the Southern States. The wings of the moths expand from $1\frac{1}{4}$ inches to $1\frac{3}{8}$ inches. The male moth, which is usually a little smaller, has its antennæ doubly feathered beneath, and those of the female possess instead two rows of minute teeth.

"The pupa state lasts from six to eight days for the summer brood, while the hibernating brood, however, requires as many months, according to the latitude in which they occur.

INJURY DONE IN 1886.

"During the past year the city of Washington, as well as its vicinity, was entirely overrun by the caterpillars. With the exception of trees and plants the foliage of which was not agreeable to the taste of this insect, all vegetation suffered greatly. The appended list of trees, shrubs, and other plants shows that comparatively few kinds escaped entirely. The fine rows of shade trees which grace all the streets and avenues appeared leafless, and covered with throngs of the hairy worms. Excepting on the very tall trees, in which the highest branches showed a few leaves too high for the caterpillars to reach, not a vestige of foliage could be seen. The trees were not alone bare, but were still more disfigured by old and new webs made by the caterpillars, in which bits of leaves and leaf-stems, as well as the dried frass, had collected, producing a very unpleasant sight. The pavements were also constantly covered with this unsightly frass, and the empty skins of the various molts the caterpillars had to undergo were drifted about with every wind, and collected in masses in corners and tree-boxes. The parks fared a little better. Because of the great variety of trees planted there some escaped entirely, while others showed the effect of the united efforts of so many hungry caterpillars only in a more or less severe degree. The grassy spots surrounding the different groups of trees had also a protective influence, since the caterpillars do not like to travel over grass, except when prompted by a too ravenous hunger. The rapid increase of this insect is materially assisted by the peculiar method of selecting shade trees for the city. Each street has, in many cases, but one kind of shade tree; rows of them extend for miles, and the trees are planted so close together that their branches almost interlace. Thus there is no obstacle at all to the rapid increase and distribution of

the caterpillars. If different kinds of trees had been planted, so as to alternate, less trouble might be experienced. Plate I shows a view of Fourteenth street, taken late in September, which illustrates this point; the poplars on the west side being completely defoliated as far as the eye can reach, while the maples on the east are almost untouched.

"As long as the caterpillars were young, and still small, the different communities remained under cover of their webs, and only offended the eye. But as soon as they reached maturity, and commenced to scatter—prompted by the desire to find suitable places to spin their cocoons and transform to pupæ—matters became more unpleasant, and complaints were heard from all those who had to pass such infested trees. In many localities no one could walk without stepping upon caterpillars; they dropped upon every one and everything; they entered flower and vegetable gardens, porches and verandas, and the house itself, and became, in fact, a general nuisance.

"The chief damage done to vegetation was confined to the city itself, although the caterpillars extended some distance into the surrounding country. There, however, they were more local, and almost entirely confined to certain trees, and mainly so to the White Poplar and the Cottonwood. Along the Baltimore and Potomac Railroad tracks these trees were defoliated as far as five miles from the Capitol. In Georgetown the caterpillars were equally noxious, but in the adjoining forests but very few webs could be seen.

"The proportionate injury to any given species of tree is to some extent a matter of chance, and in some respects a year of great injury, as 1886, is not a good year to study the preferences of a species, because when hard pressed for food the caterpillars will feed upon almost any plant, though it is questionable whether they can mature and transform on those which they take to only under the influence of such absolute necessity. Again, the preference shown for particular trees is more the result of the preference of the parent moth than of its progeny in a case of so general a feeder as the Fall Web-worm. We had a very good illustration of this in Atlantic City last autumn. The caterpillars were exceedingly abundant during autumn along this portion of the Atlantic coast, especially on the trees above named. We studied particularly their ways upon one tree that was totally defoliated by September 11. The bulk of the caterpillars were then just through their last molt, though others were of all ages illustrating different hatchings. There was an instinctive migration of these larvæ of all sizes, and the strength of their food habits once acquired from birth upon a particular tree was well illustrated. At first the worms passed over various adjacent plants, like honeysuckles, roses, etc., the leaves of which they freely devour if

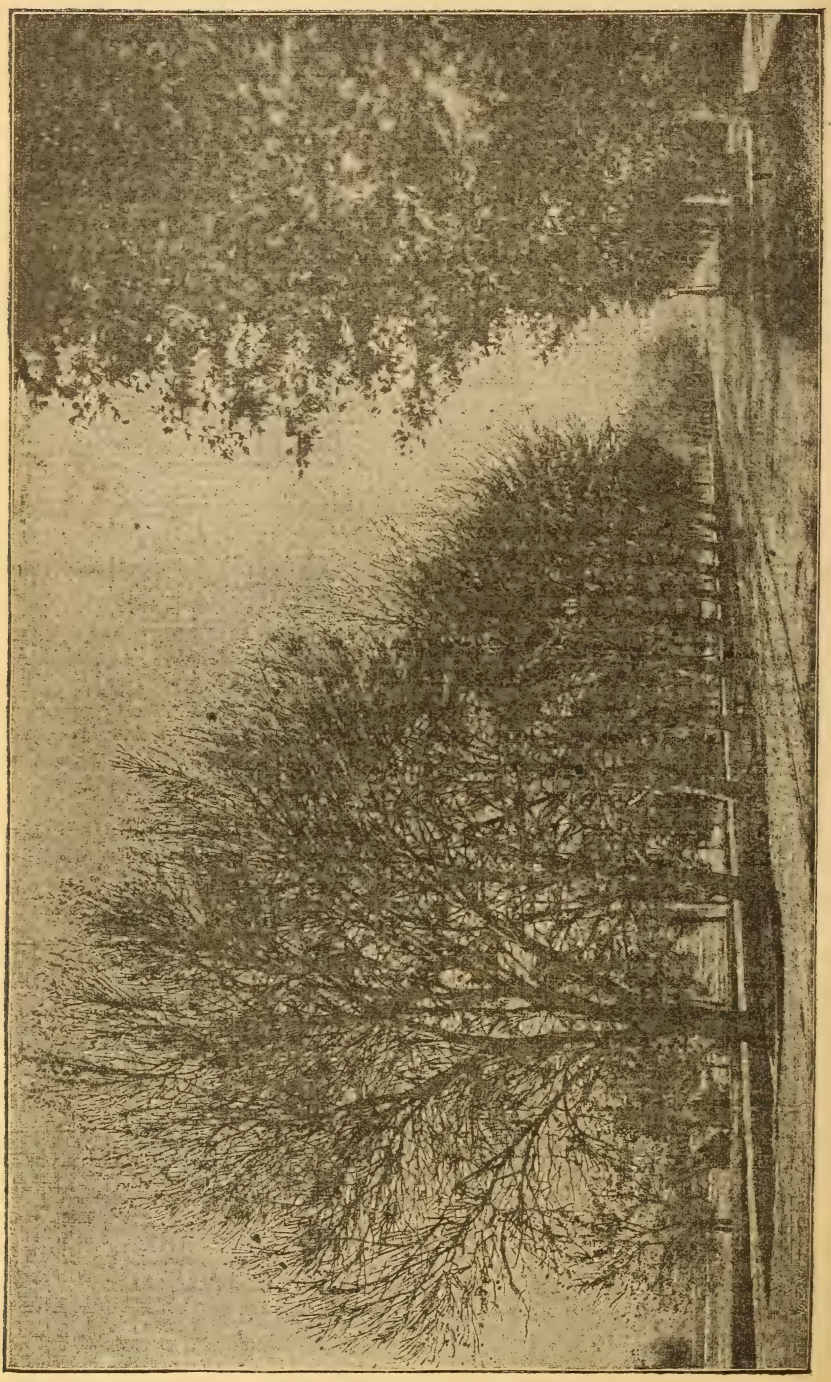

PLATE I.—TREES DEFOLIATED BY THE WEB-WORM.

hatched upon them, but as the migrating swarm became pressed with hunger they finally fell upon these, and even upon plants like the Peach, and Ailanthus, which ordinarily are passed over. They would pounce upon any food, and a rotten apple placed in their way was soon literally swarming with them and sucked dry.

"In a general way it may be stated that conifers, grapes, and most herbaceous plants are free from their attacks, and it is very doubtful whether the species can mature upon them.

"The list of plants which follows is arranged according to the relative damage to the foliage in the city of Washington. The three first named are most subject to attack, and, in fact, are almost always defoliated.

PROPORTIONATE INJURY TO DIFFERENT PLANTS AND SHADE TREES.

"The damage done in the city of Washington was exceptional, but so was also the general damage throughout the New England States, if not throughout the country. In New England the greater predilection which the species showed for Poplar, Cottonwood, and the ranker growing Willows was everywhere manifest, and so much was this the case that the destruction of the first brood on these trees would have substantially lessened the damage to other trees."

Plants marked 1 have lost from 75 to 100 per cent. of their foliage.

Plants marked 2 have lost from 50 to 75 per cent. of their foliage.

Plants marked 3 have lost from 25 to 50 per cent. of their foliage.

Plants marked 4 have lost from 0 to 25 per cent. of their foliage. Plants marked with two figures have shown the relative immunity or injury indicated by both, the variation being in individual trees.

1. *Negundo aceroides* Mœnch. (Box Elder.)
1. *Populus alba* L. (European White Poplar.)
1. *Populus monilifera* Aiton. (Cottonwood.)
1–2. *Populus balsamifera* L. (Balsam Poplar.)
1–2. *Populus tremuloides* Mich'x. (American Aspen.)
1–2. *Fraxinus americana* L. (White Ash.)
1–2. *Fraxinus excelsior* L. (European Ash.)
1–2. *Sambucus canadensis* L. (Elder.)
1–2. *Pyrus* species. (Cultivated Pear and Apple.)
1–2. *Prunus avium* and *cerasus* L. (Cherries.)
1–4. *Syringa vulgaris* L. (Lilac.)
1–4. *Ilex* spec. (Holly.)
2. *Platanus occidentalis* L. (Sycamore.)
2. *Salix* species. (Willow.)
2. *Tilia americana* L. (American Linden.)
2. *Tilia europæa* L. (European Linden.)
2. *Populus dilatata* Ait. (Lombardy Poplar.)
2. *Ulmus americana* L. (American White Elm.)
2–3. *Ulmus fulva* Mich. (Slippery Elm.)
2–3. *Prunus armeniaca* L. (Apricot.)
2–3. *Alnus maritima* Muhl. (Alder.)
2–3. *Betula alba*, L. (White Birch.)
2–3. *Viburnum* species. (Haw or Sloe.)
2–3. *Lonicera* species. (Honeysuckles.)
2–3. *Prunus americana* Marsh. (Wild Red Plum.)
2–3. *Celtis occidentalis* L. (Hackberry.)
2–3. *Rosa* species. (Rose.)
2–3. *Gossypium album* Ham. (Cotton.)
2–3. *Cephalanthus occidentalis* L. (Button Bush.)
2–4. *Convolvulus* spec. (Morning Glory.)

2-4. *Acer saccharinum* Wang. (Sugar Maple.)
2-4. *Geranium* species. (Geranium.)
3. *Betula nigra* L. (Red Birch.)
3. *Tecoma radicans* Juss. (Trumpet Creeper.)
3. *Symphoricarpus racemosus.* Mich'x. (Snowberry.)
3. *Larix europæa,* Del. (European Larch.)
2. *Corylus americana,* Walt. (Hazelnut.)
3. *Quercus alba* L. (White Oak.)
3. *Diospyros virginiana* L. (Persimmon.)
3. *Carya* species. (Hickory.)
3. *Juglans* species. (Walnut.)
3. *Wistaria sinensis* Del. (Chinese Wisteria.)
3. *Wistaria frutescens* DC. (Native Wisteria.)
3. *Amelanchier canadensis* T. & G. (Shad-bush.)
3. *Cratægus* species. (Haw.)
3. *Rubus* species. (Blackberry.)
3. *Spiræa* species. (Spiræa.)
3. *Ribes* species. (Currant and Gooseberry.)
3. *Staphylea trifolia* L. (Bladder Nut.)
3-4. *Cydonia vulgaris* Pers. (Quince.)
3-4. *Asimina triloba* Dun. (Papaw.)
3-4. *Berberis canadensis* Pursh. (Barberry.)
3-4. *Catalpa bignonioides* Walt. (Indian bean.)
3-4. *Catalpa speciosa* Ward. (Bignonia.)
3-4. *Euonymus atropurpureus* Jaeg. (Burning Bush.)
3-4. *Cupressus thyoides* L. (White Cedar.)
3-4. *Juniperus virginiana* L. (Red Cedar.)
3-3. *Cornus florida* L. (Flowering Dogwood.)
3-4. *Cornus alternifolia* L. (Alternate-leaved Dogwood.)
3-4. *Carpinus americana* Mich'x. (Hornbeam.)
3-4. *Castanea americana* Mich'x. (American Chestnut.)
3-4. *Castanea pumila* Mich'x. (Chinquapin.)
3-4. *Ostrya virginica* Willd. (Hop Hornbeam.)
3-4. *Quercus coccinea* Wang. (Scarlet Oak.)
3-4. *Quercus phellos* L. (Willow Oak.)
3-4. *Quercus prinus* L. (Chestnut Oak.)
3-4. *Quercus rubra* L. (Red Oak.)
3.4. *Diospyros kaki* L. (Japan Persimmon.)
3-4. *Buxus sempervirens* L. (Common Box.)
3-4. *Hamamelis virginica* L. (Witch Hazel.)
3-4. *Sassafras officinale* Ness. (Sassafras.)
3-4. *Cercis canadensis* L. (Red Bud.)
3-4. *Hibiscus syriacus* L. (Tree Hibiscus.)
3-4. *Rhamnus alnifolius* L'Her. (Alder-leaved Buckthorn.)
3-4. *Prunus virginiana* L. (Choke Cherry.)
3-4. *Persica vulgaris* Mill. (Peach.)
3-4. *Æsculus hippocastanum* L. (Horse Chestnut.)
3-4. *Paulownia imperialis* Seeb. (Cigar Tree.)
3-4. *Ailanthus glandulosus* Daf. (Tree of Heaven.)
3-4. *Maclura aurantiaca* Nutt. (Osage Orange.)
3-4. *Ampelopsis quinquefolia.* Virginia Creeper.)
3-4. *Clematis* species. (Clematis.)
3-4. *Trifolium* spec. (Clover.)
3-4. *Helianthus* spec. (Sunflower.)
3-4. *Jasminum* spec. (Jesamine.)
3-4. *Ficus carica* L. (Fig.)
4. *Rhus cotinus* L. (Smoke Tree.)
4. *Pinus* spec. (Pine.)
4. *Taxus* spec. (Yew.)
4. *Nyssa multiflora* Wangerh. (Sour Gum.)
4. *Fagus ferruginea* Ait. (Beech.)
4. *Kalmia* spec. (Laurel.)
4. *Rhododendron* spec. (Rhododendron.)
4. *Ricinus communis* L. (Castor-oil Plant.)
4. *Liquidambar styraciflua* L. (Sweet Gum.)
4. *Gleditschia triacanthos* L. (Honey Locust.)
4. *Gymnocladus canadensis,* Lamb. (Kentucky Coffee Tree.)
4. *Robinia pseudacacia* L. (Locust.)
4. *Liriodendron tulipifera* L. (Tulip Tree.)
4. *Magnolia* spec. (Magnolia.)
4. *Chionanthus virginicus* L. (Fringe Tree.)
4. *Ligustrum vulgare* L. (Privet.)

4. *Zanthoxylum americanum* M. (Prickly Ash.)
4. *Acer dasycarpum* Ehrh. (White or Silver Maple.)
4. *Acer rubrum* Wangert. (Red Maple.)
4. *Æsculus flava*, Ait. (Sweet Buck-eye.)
4. *Æsculus glabra* Willd. (Ohio Buck-eye.)
4. *Morus rubra* L. (Red Mulberry.)

"Trees in the vicinity of the White Poplar and Cottonwood suffered most. Even trees usually not injured, as, for instance, the Sugar Maple, are often badly defoliated when in such contiguity.

"This list contains a number of plants not usually injured by these caterpillars. In some cases the injury was due to the fact that twigs containing the web, with its occupants, had been pruned from the tree and thrown near plants, instead of being at once burned or otherwise destroyed.

"In other cases the injury is due to the peculiar position of the plant injured, *i. e.*, under a tree infested by the caterpillars. These when fully grown commence to scatter, and dropping upon the plants underneath the tree so defoliate it without actually making their home upon it. The great number thus dropping from a large tree will soon defoliate any smaller plant, even if each caterpillar takes but a mouthful by way of trial. Thus Holly, a plant not usually eaten by these insects, soon becomes denuded. Other plants unpalatable or even obnoxious to the caterpillars are sometimes destroyed by the multitudes in their search for more suitable food.

"Hungry caterpillars leaving a denuded tree in search of food wander in a straight line to the next tree, sometimes a distance of 25 feet, showing that they possess some keen sense to guide them. If such a tree offers unsuitable food, they still explore it for a long time before deserting it. In this manner two columns of wandering caterpillars are formed, which frequently move in opposite directions.

PECULIAR EFFECT OF DEFOLIATION UPON SOME PLANTS.

"During the early part of October many trees, mainly apple and pear, which had been entirely denuded of their foliage by the caterpillars, showed renewed activity of growth. Some had a few scattered flowers upon them, others had one or two branches clothed with flowers, while in some few cases the whole tree appeared white. It looked as if the trees were covered with snow, since they lacked the green foliage usually seen with the blossoms in spring. Some few flowers were also observed upon badly defoliated cherry-trees. Even as late as the middle of November, owing perhaps also to the pleasantly warm weather, some few flowers could be observed upon some imported plants belonging to the genus *Spiræa* and upon the Chinese Red-apple. All these plants usually blossom early in spring. The caterpillars having entirely defoliated the trees produced thus an artificial period of rest, or winter, which was followed by unseasonable budding and flowering. Such a

result often follows summer denudation by any insect, and we have referred to some remarkable cases in our previous writings.*

ENEMIES OF THE WEB-WORM OTHER THAN INSECTS.

"The caterpillars have comparatively few enemies belonging to the vertebrate animals. This is not owing to any offensive odor or to any other means of defense, but is entirely due to their hairiness. Chickens, and even the omnivorous ducks, do not eat them; if offered to the former they pick at these morsels, but do not swallow them.

"The English sparrow has, in this case at least, not proven of any assistance whatever. Indeed, as before stated, its introduction and multiplication has greatly favored the increase of the worms.

"The 'pellets' of a Screech-owl (*Scops asio*) found in the vicinity of Baltimore, Md., and examined by Mr. Lugger, consisted apparently almost entirely of the hairs of these caterpillars, proving that this useful bird has done good service.

"Perhaps the statement may be of interest, that this little owl is getting much more common in the vicinity of such cities, in which the English sparrow has become numerous, and that the imported birds will find in this owl as bold an enemy as the Sparrow-hawk is to them in Europe, and even more dangerous, since its attacks are made towards dusk, at a time when the sparrow has retired for the night and is not as wide awake for ways and means to escape.

"If our two cuckoos, the black-billed as well as the yellow-billed species, could be induced to build their nests within the city limits or in our parks, we should gain in them two very useful friends, since they feed upon hairy caterpillars.

"The common toad (*Bufo americana*) has eaten great numbers of these caterpillars, as shown by dissections made by Mr. Lugger, and it should be carefully protected instead of being tormented or killed by boys or even grown people. The toad is always a useful animal and ought to be introduced in all gardens and parks.

"The following species of spiders were observed to eat the caterpillars, viz, *Marpessa undata* Koch and *Attus* (*Phydippus*) *tripunctatus*. Neither species builds a web, but obtains its prey by boldly leaping upon it; they are, in consequence of such habits, frequently called Tiger-spiders. The former was exceedingly common last year, more so than for many previous years, thus plainly indicating that the species did not suffer for lack of food. This species is usually found upon the trunks of trees, and is there well protected by its color, which is like that of the bark. It hides in depressions and cracks of the bark, and, jumping upon the passing game, or, cat-like, approaching it from behind, it thrusts its poisonous fangs into the victim, which soon dies and is sucked dry. The *Attus* has similar habits, but is still more cautious; it usually hides

* See Eighth Report on the Insects of Missouri, p. 121.

under loose bark. Both spiders are wonderfully active, and kill large numbers of caterpillars. Their large flat egg masses can be found during the winter under dead bark and in cracks. Both species hibernate in silken nests in similar localities."

PREDACEOUS INSECT ENEMIES.

The caterpillars of this moth have quite a number of external enemies, which slay large numbers of them. The well-known Rear-horse (*Mantis carolina*, see Fig. 20) seems to be very fond of the caterpillars.

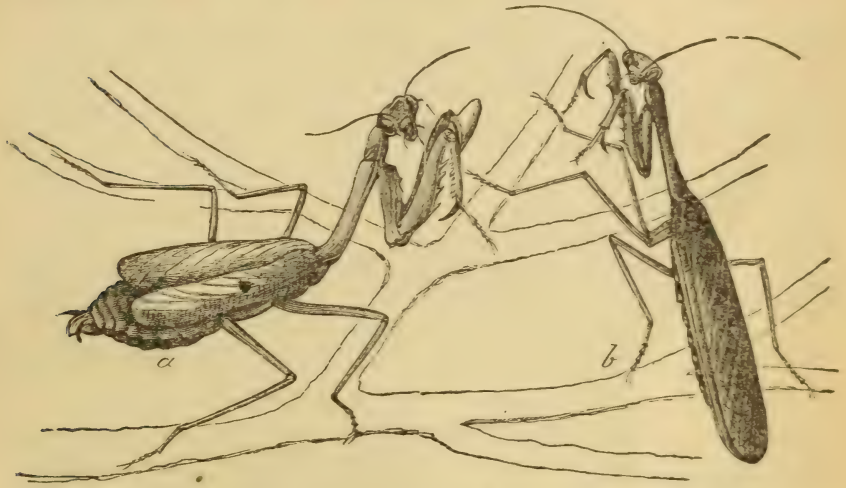

FIG. 20.—*Mantis carolina*: *a*. female: *b*. male.

The so-called Wheel-bug (*Prionidus cristatus*, see Fig. 16) has proved to be one of our best friends in reducing the numbers of the caterpillars. This insect was formerly by no means very common in cities, but of late years it has greatly increased in numbers, and is now a well-known feature in all our public parks and such streets as possess shade-trees. Outside of the city it is rarely met with; nor does it extend much farther north than Washington. It is, like the Mantis, in all its stages a voracious feeder upon insects, slaying alike beneficial and noxious ones. The bright red larvæ and pupæ, also carnivorous, are seen in numbers during the summer; they usually remain together until hunger forces them to scatter. They assist each other in killing larger game, and are to this extent social. The Wheel-bug could be observed almost anywhere last summer, usually motionless, stationed upon the trunk of trees, waiting for the approach of an insect. If one comes near, it quite leisurely inserts its very poisonous beak, and sucks the life-blood of its victim. When this becomes empty it is hoisted up in the air, as if to facilitate the flow of blood, until eventually it is thrown away as a mere shriveled skin. The appetite of the Wheel-bug is remarkable, whenever chances offer to appease it to the fullest extent. Frequently,

however, times go hard with it, and notwithstanding it is very loth to change a position once taken, it is sometimes forced to seek better hunting grounds, and takes to its wings. The Wheel-bug has been observed to remain for days in the same ill-chosen position, for instance upon the walls of a building, waiting patiently for something to turn up. It is slow in all its motions, but withal very observant of everything occurring in its neighborhood, proving without doubt great acuteness of senses. It does not seem to possess any enemies itself, and a glance at its armor will indicate the reason for this unusual exemption.* During warm weather this bug possesses a good deal of very searching curiosity, and a thrust with its beak, filled with poison, is very painful indeed. Boys call it the Blood-sucker, a misnomer, since it does not suck human blood. The eggs are laid during the autumn in various places, but chiefly upon smooth surfaces of the bark of tree-trunks, and frequently in such a position as to be somewhat protected against rain by a projecting branch. The female bug always selects places the color of which is like that of the eggs, so they are not easy to see, notwithstanding their large size.

"*Euschistus servus* Say, is another hemipterous insect that preys upon the caterpillar of *H. cunea*, and in a similar manner to the Wheel-bug. It is a much smaller, but also a very useful insect.

"*Podisus spinosus* Dall. (Fig. 21), in all its stages was quite numerous during the caterpillar plague. Its brightly-colored larvæ and pupæ (Fig. 22) were usually found in small numbers together; but as they grew older they become more solitary in their habits. All stages of this insect frequent the trunk and branches of trees, and are here actively engaged in feeding upon various insects. As soon as one of the more mature larvæ or a pupa has impaled its prey, the smaller ones crowd about to obtain their share. But the lucky captor is by no means willing to divide with the others, and he will frequently project his beak forward, thus elevating the caterpillar into the air away from the others. The habit of carrying their food in such a difficult position has perhaps been acquired simply to prevent others from sharing it. A wonderful strength is necessary to perform such a feat, since the caterpillar is sometimes many times as heavy as the bug itself. The greediness of this bug was well illustrated in the following observations: A pupa of *P. spinosus* had impaled a caterpillar, and was actively engaged in sucking it dry; meanwhile a Wheel-bug utilized a favorable opportunity and impaled the pupa, without forcing the same to let go the

FIG. 21.—*Podisus spinosus*: *a*, enlarged beak; *b*, bug, with right wings expanded.

FIG. 22.—*Podisus spinosus*: *a*, pupa; *b*, larva; *c*, egg.

* The eggs of the Wheel-bug are pierced, however, by a little egg-parasite—*Eupelmus reduvii* Howard.

caterpillar. The elasticity of the beak (Fig. 21*a*) of these bugs must be very great; they can bend it in any direction, and yet keep it in sucking operation. The poison contained in the beak must act very rapidly, since caterpillars impaled by it squirm but for a very short time, and then become quiet."

FUNGUS DISEASES OF THE WEB-WORM.

"The first brood of these caterpillars showed in some quite well-defined localities the indications of a fungus disease.* This did not become, however, as general as later in the season, when it prevailed everywhere; yet it could be observed that the contagion had started from certain points. In such localities almost all the caterpillars were diseased and large numbers of the dead were huddled together as in life. But when investigated their bodies were hard and dry, and would readily crumble to pieces when pressed, producing an odor like that of some mushrooms. Only full-grown, or rather caterpillars in their last larval stage, were thus affected. The dry remains had retained the original shape, and, if killed but recently by the fungus, their color as well. Before dying the caterpillars had fastened themselves very securely to trunks, twigs, and leaves of various trees, somewhat like the common house-fly, that dies by a similar disease in large numbers during September in our houses, and produces around itself such a characteristic halo of white spores. Caterpillars infested by the incipient stages of this disease wander about aimlessly and at an irregular speed; often they halt for some time, then squirm about frantically to start again, and frequently in an opposite direction to the one they were going before. If such a diseased caterpillar is confined to a glass jar and observed it is soon seen that a white mealy substance gradually grows out of all the soft spaces between their segments, which eventually covers the whole insect, leaving generally only the black head and tips of hairs visible. Before long many spores are scattered about, forming a circle of white dust around the caterpillar, and, if not arrested by an obstruction in its expulsion, the halo thus formed is quite regular and about 2 inches in diameter. Outdoors this white dust is but seldom observed, because even the slightest draft of air will carry it away and drift it about. Even the white mealy substance adhering to the caterpillar itself is usually swept away, and the victims look very much like healthy caterpillars; but they darken with time and eventually drop to the ground. The magnifying glass, however, still reveals some spores adhering to the hairs, upon the underside, and upon the bark or leaf of the tree in their immediate neighborhood.

"This fungus kills caterpillars even after they have made their cocoons. Nor does the pupa escape. In the latter case the spores form a white crest over every suture of the thoracic segments; the abdominal segments, however, remain free from it. Evidently the caterpillars were nearly full-grown when attacked by the disease, and possessed

* This fungus has been determined by Mr. Roland Thaxter as *Empusa grylli*.

vigor enough to transform into pupæ; later the fungus grew, and, pressing the chitinous portion of the pupa apart, forced its way to the air to fructify.

"Plants not usually eaten by the caterpillars, as well as others not eaten at all, have upon them the largest numbers of caterpillars killed by the fungus, provided that they grow in the vicinity of suitable food-plants. Perhaps unsuitable food, predisposing the caterpillars for any disease, is one of the causes of the innumerable host killed by this fungus.

"The white cocoons of a parasite (*Apanteles hyphantriæ* Riley) of this caterpillar were in some cases observed to be covered with similar spores of a fungus. Opening such cocoons it was seen that the spores were not simply blown upon the silk and there retained, but that they came from the victim within, and had forced their way through the very dense silken covering."

Experiments to obtain percentage of diseased caterpillars.

Experiment I:

One hundred and twenty-five nearly grown caterpillars were gathered (October 7, 1886) at random in one of our public parks. They were imprisoned in large glass jars and daily supplied with suitable food.

Result, October 18, 1886:

11	apparently healthy pupæ.
3	deformed pupæ.
18	yellow cocoons of *Meteorus hyphantriæ*.
9	dead pupæ, killed by fungus or otherwise.
84	dead caterpillars, killed by fungus or otherwise.
125	

In the earth of the jar were found 17 pupæ of Tachina flies, leaving 67 caterpillars and 9 pupæ killed by the fungus, or 61 per cent.

Experiment II:

One hundred and twenty-five nearly grown caterpillars were gathered (October 7, 1886) from a trunk of a Soft Maple tree (unsuitable food) and treated as above.

Result, October 18, 1886:

8	apparently healthy pupæ.
1	deformed pupa.
7	yellow cocoons of *Meteorus hyphantriæ*.
3	dead pupæ, killed by fungus or otherwise.
104	dead caterpillars, killed by fungus or otherwise.
2	cocoons containing Tachina larvæ.
125	

In the earth of the jar were found 28 pupæ of Tachina flies, leaving 76 caterpillars and 3 pupæ killed by fungus, or 63 per cent.

In both experiments it has been assumed that each Tachina fly had killed one caterpillar.

On November 15, 1886, the jars were again investigated, and it was found that a number of the pupæ had been killed by the fungus since October 18, 1886, and that in fact all the remaining ones did not look healthy. The percentage of death by the fungus in the two experiments was thus increased to 63 per cent. in Experiment I and to 67 per cent. in Experiment II.

TRUE PARASITES OF THE WEB-WORM.

Up to the present time no parasites of this insect have ever been recorded. On August 18, 1883, we bred a number of egg-parasites from a batch of eggs found upon a willow leaf at Washington, but unfortunately no description was made of them at the time, and, as they belonged to the soft-bodied genus *Trichogramma*, the specimens have now become so much shriveled and altered that they are unfit for descriptive purposes. We noticed after our return from Europe in September of this year that, at a number of points in New England, the worms were quite commonly attacked by parasites, and careful investigation at Washington by Mr. Lugger showed the presence of no less than five distinct species of primary parasites in addition to the *Trichogramma* just mentioned. These will be considered in some detail. The first was a new egg-parasite which we have named *Telenomus bifidus;* the others were all parasitic on the larvæ, and consisted of a Braconid (*Meteorus hyphantriæ* n. sp.); a Microgaster (*Apanteles hyphantriæ*, n. sp.); an Ophionid (*Limneria pallipes* Prov.), and a Tachinid, which, though probably new, we shall not attempt to describe. These last four have been mentioned in about the order of their relative abundance and consequent importance. An astonishing number of Web-worms were killed by the four parasites, and so many died from this cause and from the fungus disease previously mentioned as to fully warrant the prediction of almost complete immunity for the summer of 1887.

In addition to these parasites found last fall, the note-books of the Division show a prior breeding of another primary parasite, which will not be treated in detail here on account of insufficient material. It is an external feeder on the larva and belongs to the genus *Euplectrus*. It is closely related to *E. platyhypenæ*, described by Mr. Howard in Bulletin 5 of this Division.

Telenomus bifidus Riley.—A single egg of the moth of *H. cunea* is a very small affair, yet it is large enough to be a world for a little parasite, which undergoes all its transformations within it, and finds there all the food and lodgement required for the short period of its life.

In several instances batches of eggs of this moth were parasitized, and instead of producing young caterpillars they brought forth the tiny insects of this species. The batches of parasitized eggs were found July 27 upon the leaves of Sunflower, and August 18 upon leaves of Willow; judging from these dates it was the second brood of moths that had deposited them. There can be no doubt, however, that eggs

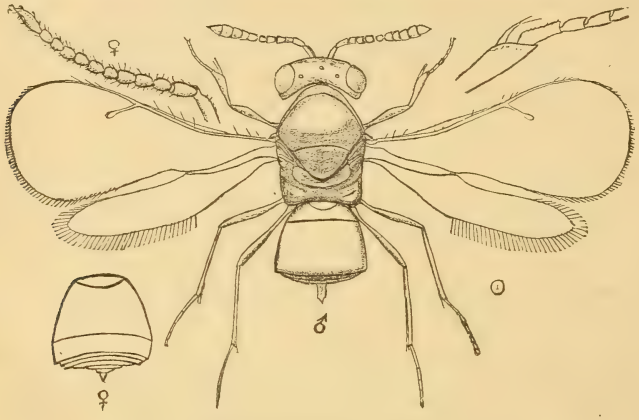

FIG. 23.—*Telenomus bifidus* (greatly enlarged).

produced by moths emerging from their cocoons in early spring had been parasitized as well. The female *Telenomus* was also observed, August 2, busily engaged in forcing its ovipositor into the eggs, and depositing therein. The female insect is so very intent upon its work that it is not easily disturbed, and one can pluck a leaf and apply a lens without scaring it away. The eggs soon hatch inside the large egg of the moth, and the larvæ produced soon consume the contents. This egg-parasite is a very useful friend, nipping the evil in the bud, so to speak.

Meteorus hyphantriæ Riley.—"This parasite (Fig. 24) has performed very good services during the caterpillar plague and has done much to check any further increase of the Web-worm. During the earlier part of the summer this insect was not very numerous, but sufficient proofs in the form of empty cocoons were observed to indicate at least one earlier brood. Towards the end of September, and as late as the 15th of October, very numerous cocoons of a second brood were formed; they could be found in all situations to which the caterpillar itself had access. But the great majority of them were suspended from the trunks and branches of trees, and chiefly from near the base of the trunk. Each cocoon represents the death of one nearly full-grown caterpillar, since the latter harbors but one larva of the parasite.* A careful watch was kept to see how such a suspended cocoon was formed,

* In only one instance the cocoon of this parasite was found inside that of its host.

but in vain. Once a larva had just started to make a cocoon, but it was prevented from finishing it by a secondary parasite, and it died. Another larva had already spun the rough outside cocoon, but became detached and dropped out of the lower orifice, and commenced a new one. The larva, suspended by the mandibles, evidently spins at first loose, irregular, horizontal loops around its body, until a loose cradle is formed. The silk secreted for this purpose hardens very rapidly when exposed to the air. When secure inside this cradle it lets go its hold with the mandibles, and finishes the soft inside cocoon in the usual manner. If the larva has dropped to the ground it still makes an outer loose cocoon, but the silken threads are thicker and much more irregular. In cocoons made during a high wind the threads that suspend them are much longer, reaching sometimes the length of 4 inches; the more normal length varies from 1½ to 2 inches.

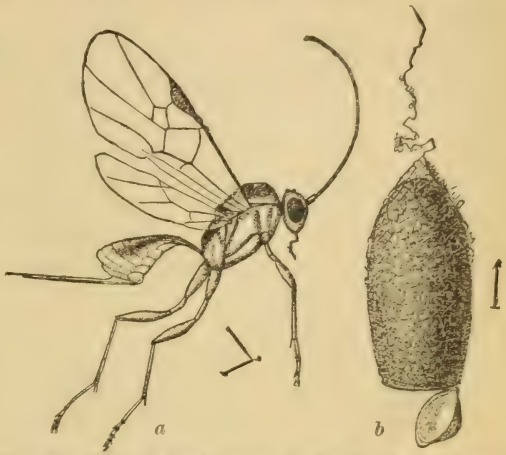

FIG. 24.—*Meteorus hyphantriæ*: *a*, female; *b*, cocoon (enlarged).

"To find out the length of time which this insect occupies in maturing inside the cocoon, 44 freshly-made cocoons were put in a glass jar. With a remarkable regularity but ten days were consumed by the insect in changing from the larval to the winged form. The winged *Meteorus* issues through a perfectly round hole at the lower end of the cocoon by gnawing off and detaching a snugly-fitting cap. There are several secondary parasites of the *Meteorus* which we may mention later, and they always leave the cocoon of their host by smaller holes cut through the sides. Most of the adults had issued by the first of November, but it is possible that some may remain in their cocoons until spring.

"In order to obtain the proportion between the *Meteorus* raised from cocoons and its parasites, *i. e.*, secondary parasites of *Hyphantria*, 450 cocoons were confined in a glass jar the latter part of September. Up to the first week in November only 70 specimens of *Meteorus* were bred from these cocoons, the rest giving out secondary parasites, which continued to issue up to date of writing (December 20, 1886). Thus, only 16 per cent. of the cocoons produced the primary, while 84 per cent. produced secondary parasites."

Apanteles hyphantriæ Riley (Fig. 25 represents a closely allied species).—"This insect was about as numerous as the *Perilitus communis*,

and did equally good service in preventing a further increase of the caterpillars. It appeared somewhat earlier in the season, and killed only half-grown caterpillars. From the numerous old and empty cocoons in early summer it was plainly seen that a first brood had been quite numerous, and that from these cocoons mainly *Apanteles* had been bred, and not, as during the autumn, mostly secondary parasites. The white silky cocoon is formed almost under the middle of a half-grown caterpillar, and is fastened securely to the object its host happened to rest upon, and but slightly to the host itself, which is readily carried to the ground by wind and rain, and can therefore only be found in position in the more sheltered places, such as cracks and fissures of the bark of trees. But one *Apanteles* is found in a caterpillar, so that each

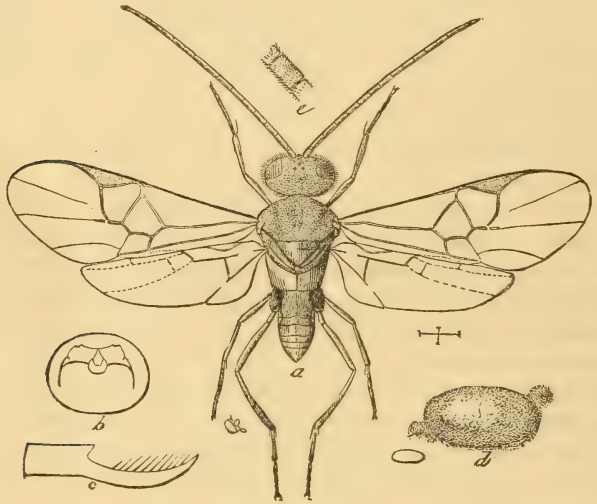

FIG. 25.—An *Apanteles*: *a*, female fly; *b*, outline of head of larva in position to show the chitinized parts of the mouth, the mandibles not visible, being withdrawn; *c*, one of its mandibles as seen within the head of a mounted specimen; *d*, cocoon; *e*, joint of antenna—all enlarged; natural size of *a* and *d* in hair-line.

white cocoon indicates, like a tombstone, the death of a victim. In some places, and notably upon the trunks of poplars, these cocoons were so numerous as to attract attention; it seemed as if the trunk had been sprinkled with whitewash. But notwithstanding such vast numbers, but two specimens of the architects of these neat cocoons were raised; all the rest had been parasitized by secondary parasites. It is barely possible, however, that some specimens may hibernate in their cocoons, since numbers of them have as yet (December 20, 1886) not revealed any insects. The winged *Apanteles* leaves the cocoon by a perfectly round orifice in the front, by cutting off a little lid, which falls to the ground. Its parasites, however, leave by small holes cut through the sides. These secondary parasites were very common late in September and

early in October, and busily engaged in inserting their ovipositors through the tough cocoon into their victim within. It seems as if the cocoons formed early in the season were on an average a little smaller than those formed later.

"The cocoons of this *Apanteles* are of a uniform white color, but exceptionally a distinctly yellowish cocoon is found. From these yellow cocoons nothing has so far been bred; but since, as we have elsewhere shown,* the color of the cocoon may vary in the same species, it is probable that the variation here referred to is not specific.

"Not quite one-half of 1 per cent. produced parasites of various kinds.

"*Limneria pallipes* Provancher.—In addition to the two Hymenopterous parasites treated of, a third one has been very numerous, and has done much good in reducing the numbers of caterpillars. This, an Ichneumonid and a much larger insect, does not form an exposed cocoon like that of the other parasites described. Yet a little attention will soon reveal large numbers of them. Upon the trunks of various trees, but chiefly upon those of the poplars and sugar maples, small colonies of caterpillars, varying in numbers from four to twelve, could be observed, which did not show any sign of life. When removed from the tree they appeared contracted, all of the same size, and pale or almost white. A closer inspection would reveal the fact that the posterior portion of the caterpillar had shrunken away to almost nothing, whilst the rest was somewhat inflated and covered with an unchanged but bleached skin, retaining all the hairs in their normal position. Opening one of these inflated skins, a long, cylindrical, brown cocoon would be exposed; this is the cocoon of the *Limneria* under consideration. As numbers of such inflated skins would always occur together, it was clearly seen that the same parent *Limneria* had oviposited in all of them. Most of the cocoons were found in depressions of the rough bark or other protected places. Single ones were but rarely met with. The Hyphantria larva in dying had very securely fastened all its legs into the crevices of the bark, so that neither wind or rain could easily dislodge them. Only half-grown caterpillars had thus been killed. Many of these inflated skins showed in the early part of October a large hole of exit in their posterior and dorsal ends, from which the ichneumons had escaped. Trying to obtain winged specimens of this parasite one hundred and forty of these cocoons—and only such as were not perforated in any way—were collected and put in a glass jar. Only a single female was produced from all up to time of writing, whilst very large numbers of secondary parasites issued from October 11 till the 20th of November, and doubtless others will appear during the spring of 1887, because some of these inflated skins show as yet no holes of exit.

"*Tachina* sp. (Fig. 26).—The parasites of *H. cunea* described so far all belong to the order Hymenoptera, which furnishes the greatest num-

*Notes on North American Microgasters, p. 7 (author's edition).

ber of them. But the fly now to be described is fully as useful as any of the others.

"Tachina-flies are very easily overlooked, because they resemble large house-flies, both in appearance and in flight, and their presence out of doors is not usually noticed on that account. Yet they play a very important rôle, living as they do in their larval state entirely in insects. During the caterpillar plague such flies were often seen to dart repeatedly at an intended victim, buzz about it, and quickly disappear. If the caterpillar thus attacked was investigated, from one to four yellowish-white, ovoid, polished, and tough eggs would be found, usually fastened upon its neck, or some spot where they could not readily be reached. These eggs are glued so tightly to the skin of the caterpillar that they can not easily be removed. Sometimes as many as seven eggs could be counted upon a single caterpillar, showing a faulty instinct of the fly or flies, because the victim is not large enough to furnish food for so many voracious maggots. If the victim happens to be near a molt, it casts its skin with the eggs and escapes a slow but sure death. But usually the eggs hatch so soon that the small maggots have time to enter the body of the caterpillar, where they soon reach their full growth, after which they force their way through the skin and drop to the ground, into which they enter to shrink into a brown, tun-like object (known technically as the coarctate pupa), which contains the true pupa. The caterpillar, tormented by enemies feeding within it, stops feeding and wanders about for a long time until it dies. As a rule not more than two maggots of this fly mature in their host, and generally but one. The caterpillar attacked by a Tachina-fly is always either fully grown or nearly so.

"Tachina-flies abounded during the whole term of the prevalence of the caterpillars. But it is impossible to state positively whether they were all bred from them or not, since the many species of this genus of flies resemble each other so closely that a very scrutinizing investigation would have been necessary to settle such a question. But there is no doubt that they were very numerous during the summer. Some maggots obtained from caterpillars kept for this purpose in breeding jars changed to the fly in six days; others appeared in twenty-three days, and still others, obtained at about the same time, are still under ground, where they will hibernate. The maggots of these flies do not, however, always enter the ground, as some were found inside cocoons made by caterpillars among rubbish above ground."

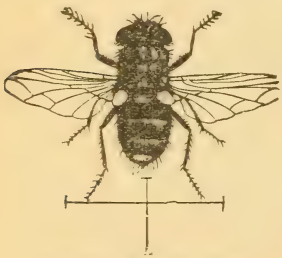

FIG. 26.—A Tachina-fly.

We have found, moreover, that three of these primary parasites of the Web-worm, viz, the *Apanteles*, the *Limneria*, and the *Meteorus*, were killed off at a serious rate late in the season by secondary parasites,

most of which belong to the family *Chalcididæ*, with the exception of three species of the Ichneumonid genus *Hemiteles*. So extensive has been this killing off of the primary parasites by the secondary, that were not the fates of the three classes, viz, the plant-feeder, the primary and the secondary parasites so interwoven, the destruction of these beneficial insects might be considered a serious matter in dealing with the plant-feeder.

We have not taken time to determine these secondary parasites specifically, but give a little table showing the number of species concerned, mentioning them only by their genera:

SECONDARY PARASITES.

On *Apanteles:*

1. *Hemiteles* sp.
2. *Elasmus* sp.
3. *Eupelmus* sp.
4. *Panstenon* sp.
5. *Cirrospilus* sp.
6. *Pteromalus* sp.
7. *Pteromalus* sp.

On *Meteorus hyphantriæ*.

1. *Hemiteles* sp. (= 1 on *Apanteles*).
2. *Spilochalcis* sp.
3. *Hemiteles utilis* Nort.
4. *Eupelmus* sp. (= 3 on *Apanteles*)
5. *Hemiteles* sp.
6. *Pteromalus* sp. (= 6 on *Apanteles*).
7. *Pteromalus* sp. (= 7 on *Apanteles*).

On *Limneria pallipes* Prov.:

1. *Eupelmus* sp. (= 3 on *Apanteles*).
2. *Tetrastichus* sp.
3. *Pteromalus* sp. (= 6 on *Apanteles*).
4. *Pteromalus* sp. (= 7 on *Apanteles*).
5. *Elasmus* sp. (= 2 on *Apanteles*).

The observations just recorded were made in the main during the summer of 1886, a season of exceptional abundance of the worms. We may add that, in accordance with our predictions in the first edition of this Bulletin, there was an immense decrease in the number of the worms with the opening of the spring of 1887. So many had been taken off by the fungus disease and by parasites that the result was that except in a few streets the worms did not become abundant. Moreover, the parking commission sent out carts and men as soon as the webs had begun to be easily seen, and so thoroughly were the nests destroyed that the second generation of worms attracted no attention whatsoever.

Moreover, whole rows of old Silver-leaved Poplars (*Populus alba*), more than 1,500 in all, were cut down during the winter of 1887–'88, and their places filled by young Red Oaks, Sugar Maples, and Silver Maples. Many of the Box Elders were also taken down, although these were in the main young trees. A number of old tree boxes were removed, and where the tree was large enough to stand up by itself and simply needed protection from horses, a coarse wire screen was substituted for the box with good effect.

SUMMARY OF THE HABITS OF THE FOUR SPECIES.

It follows from the above that we have to deal with four very different insects, each of them requiring modification in treatment, especially so far as winter work is concerned. Here, as in every other case in dealing with injurious insects, correct knowledge of the habits of the species to be dealt with must necessarily precede intelligent action, else we shall be apt to err, as did the authorities of our neighboring city, Baltimore, many years ago, by incurring a great deal of unnecessary expense without producing any beneficial result. Their blunder is historical. Observing that the elm trees around Cambridge, Mass., suffered from defoliation and were effectually protected by troughs of oil around the trunk, they ordered similar troughs of oil to be placed around their trees in Baltimore, which were also being defoliated. In Cambridge, however, the insect involved was the Spring Canker Worm (*Paleacrita vernata*), which has a wingless female that issues from the ground early in spring, and is effectually prevented by the oil troughs from ascending the trees; whereas the trees in Baltimore were suffering from the Galeruca, which we have just described, and which has ample wings in both sexes.

1. The imported Elm Leaf-beetle is a small yellowish beetle, about a quarter of an inch long, and marked with two longitudinal dark stripes on the back. It passes the winter in the beetle state in holes and crevices in the bark of trees, in fences and tree-boxes, in barns and out-houses, etc., and the eggs are laid on the young leaves of elms in April and May. The eggs are yellowish, elongate, and pointed, and are laid on end upon the leaves in groups of from five to twenty or more. The resulting worm feeds on the leaves, gradually skeletonizing and gnawing holes through them. The larvæ molt four times and transform to pupæ at the surface of the ground under grass and stones. There are several broods, and and the worms are pretty constantly at work through the months of June, July, and August.

This is an imported insect, is confined to the Elm (genus *Ulmus*), has a predilection for the European Elm and for trees in cities, and the female flies long distances.

2. The Bag-worm is one of our commonest native American insects, and its bags hang from the smaller limbs of our shade trees so as to be easily seen, especially in winter, when the leaves have fallen. These bags are made by the larva or worm which lives within them. The female moth is wingless, and only leaves the bag in which she passed her larval and pupal life after she has deposited her eggs in her empty

chrysalis skin or puparium. She then falls to the ground and perishes. The eggs remain in the bag all winter and hatch in spring into young worms, which scatter and at once make new bags, which increase with their growth and protect them from the attacks of birds.

The male moth is a small, black, hairy-bodied creature, with ample transparent wings, and escapes from the chrysalis after it is partially worked out of the hind end of the bag. This worm is a very general feeder, but is, on the whole, more injurious to evergreens than to deciduous trees.

This species has several insect parasites.

3. The White-marked Tussock moth has a very beautiful hairy larva or caterpillar marked with black and yellow and red. The female cocoons are to be found during the winter on the trees and upon neighboring fences and tree-boxes, and each cocoon is plastered with a number of eggs, protected by a white, frothy, glutinous covering. The eggs hatch in spring and the young worms feed upon the fresh leaves. The males spin their cocoons after three molts and the females after four. The moths issue in July, pair and lay eggs for a second brood of worms, which in turn transform and bring forth moths in October, the eggs from which hibernate. The male moth is active, with ample wings, which are brown, with a conspicuous white spot, while the female is pale and wingless, and only crawls out of her cocoon to lay her eggs thereon and die. This species is never found on evergreens, and is chiefly injurious to elms and maples, and prefers large and old trees to young ones, because of the greater shelter which they offer for its cocoons. In Washington it is yet chiefly confined to our parks, and it has not begun to be as injurious as in cities like Philadelphia and Baltimore, where the trees are older and larger. Two probable egg-parasites and seven parasites of larva and pupa are known to me.

4. The Fall Web-worm passes the winter in the pupa state. The cocoons are found during the winter principally at the surface of the ground, mixed with dirt and rubbish, or in cracks and crevices of tree-boxes, in fences, and under door-steps and basement walls. The first moths issue from these cocoons in May, and lay their eggs in flat batches on the under side of the leaves. The young worms feed preferably in company, webbing first one and then several leaves together, and gradually extending their sphere of action until a large part of the tree becomes involved. The worms become full grown in July and spin cocoons, from which a second generation of moths issue early in August and lay eggs, from which the worms hatch; so they are once more in force by the latter part of August. This is the species which did the damage last year. The parent moth is white, with a varying number of spots; is winged in both sexes; and the female prefers to oviposit on Box Elder (*Negundo aceroides*), the Poplars, Cottonwoods, Ashes, and Willows. The worm feeds, however, on many other trees, but not upon Conifers. It has numerous enemies and parasites.

REMEDIES AND PREVENTIVE MEASURES.

WINTER WORK.

The preventive measures that can be taken during winter time vary according to the species to be dealt with. For No. 1, or the Galeruca, which is confined to the Elms, no treatment of the trees themselves or of the boxes; in fact, no treatment that can well be given in the winter season will avail much in destroying the insect in its hibernating retreats, because the parent beetle finds shelter in all sorts of out-of-the-way places. It flies long distances, especially upon awakening from its winter torpor, so that it may be attracted to the trees from regions into which it is practically impossible to effectually pursue and detect it.

With No. 2, the Thyridopteryx, on the contrary, effective work can be done during the winter time or when the trees are bare. The bags which contain the hibernating eggs, and which are very easily detected, then may be gathered or pruned and burned. This work may be so easily done that there is no excuse for the increase of this species. Where intelligent action is possible the bags were better collected and heaped together in some open inclosure away from trees, rather than burned. By this means most of the parasites will in time escape, while the young Bag-worms, which will in time hatch and which have feeble traveling power, must needs perish from inability to reach proper food.

Much can also be done with No. 3, the Orgyia, because it also hibernates in the egg state upon the female cocoons upon the trunks and in all sorts of recesses.

In regard to No. 4, the Hyphantria, which is the species we are more particularly dealing with, something also may be done in the winter time by systematic clearing away of the cocoons from the sheltered places in which they may be found. These hibernating retreats are, however, so numerous about our houses and our grounds, that complete destruction of all cocoons becomes an impossibility.

ONE SIMPLE PREVENTIVE REMEDY FOR ALL.

It so happens, fortunately, that there is one thoroughly simple, cheap and efficacious remedy applicable to all four of these tree depredators. From the natural history facts already given it is clear that they all begin their work very much at the same season or as soon as the leaves are fairly developed, and arsenical mixtures properly sprayed on the trees about the middle of May and repeated once or twice at intervals

of a fortnight later in the season, will prove an effectual protection to trees of all kinds. This can be done at small expense, and will prove the salvation of the trees. An apparatus can be readily constructed, such as has been used on the grounds of the Department of Agriculture, on a sufficiently large scale to economize time and labor. It should consist of a water tank mounted on a cart and furnished with a strong force pump operated by one man and furnished with two sets of rubber tubing of a sufficient length (a hose reel can be constructed on top of the cart), each hose supported by a bamboo extension pole with a cyclone nozzle at tip. With such an apparatus as this three men could drive along the streets and thoroughly spray two trees simultaneously; while if it were found advisable, four independent tubes and four men to work them could be employed with a sufficiently powerful pump, and thus expedite the work. The details of the more important devices connected with this tank-cart are given in considering the Galeruca. The bamboo "extension pole" is used simply to stiffen the rubber hose and to enable the operator to elevate the spraying nozzle into the center of the tree and spray to a so much greater height. The same result can be accomplished by means of a brass rod, in sections, and this has the advantage of superior strength, and will consequently carry a heavier nozzle or a bunch of nozzles at the end.

The "Cyclone" or "Eddy-chamber" nozzle (see Fig. 6) is better suited for work of this kind on small trees than any yet in use. It is small, simple, cheap, will not clog, and gives an admirable spray. A combination nozzle may be made of several of these which will be readily supported by the section rod and will throw a more profuse spray.

The arsenical compound known as London purple is, as already shown, perhaps preferable to white arsenic or Paris green in that it is not so liable to burn the leaves while its color enables one to readily distinguish poisoned from non-poisoned trees. Moreover it is very cheap. From one-quarter to three-quarters of a pound of this substance should be used to a barrel of water, and with this quantity of water it is best to mix three quarts of cheap or damaged flour which will serve both to render the mixture adhesive to the leaves and also to lessen the tendency of the poison to burn the leaves. Three-quarters of a pound to the barrel may prove too strong a mixture for delicate and susceptible young trees, and it will be best for general application to make the amount from three-eighths to one-half pound to the barrel. Paris green will require a somewhat heavier dose—say from one-half to 1 pound per barrel of water.

A number of other means have been tried and are more or less effectual in destroying these defoliators. Such are the application of various other insecticides, particularly an emulsion of milk and kerosene, the burning of the webs (in case of the web-worm) by thrusting a lighted torch, made of various patterns, into the webs; but after full trial, nothing has been found more satisfactory than the arsenical mixtures

here recommended. They have the advantage over all other means that they kill directly the worms begin feeding, and at the same time have a preventive influence. Properly sprayed on the under side of the leaves so as to adhere, they are not easily washed off, and they not only kill, without injury to the tree, all the worms at the time upon such tree, but all those which may hatch upon such tree for a number of days and even weeks subsequently.

We are satisfied that with two or three special tanks, such as we have built at the Department of Agriculture, and a gang of three men to each, the trees of the city could be easily protected at a nominal cost beyond labor, and that two sprayings, one about the middle of May and one the first week in June, will effectually prevent the repetition of any such nuisance as that we suffered from last summer. Each gang of three men could properly protect in the neighborhood of from three hundred to five hundred medium-sized trees per day, and in ordinary seasons and in dealing with the web-worm it would only be necessary to poison such trees as are preferred by the insect.

We may here with propriety describe, as supplementary to the general consideration of machinery on pp. 19–22, two recently-invented machines which could be used to advantage in this work.

The first is the invention of Mr. A. H. Nixon, of Dayton, Ohio, and will answer very well for the spraying of arsenical solutions. The cyclone nozzle, with all its advantages on small or medium-sized trees, is not so well adapted for spraying very high trees, and Mr. Nixon's nozzle and several others which might be mentioned have an advantage in that they throw a spray to a greater height or distance, in a more powerful and narrower stream, which nevertheless breaks up into a floating spray.

We have personally tested Mr. Nixon's nozzle and find it is a very satisfactory one. Mr. W. B. Alwood, the agent of the Division at Columbus, Ohio, in a report upon it, writes:

"The necessity of a good apparatus for spraying tobacco in a packing-house led Mr. Nixon to experiment with many different kinds of apparatus, until almost by accident he discovered that a jet of water projected against a wire gauze of proper sized mesh held at a certain distance would produce a perfect spray. He was several years in working up a scheme to utilize this newly discovered fact, and then succeeded very imperfectly, but produced an apparatus which found quite common use in his and other tobacco warehouses in the Miami Valley.

"However, some three years ago he conceived the notion of perfecting his nozzle and bringing it into shape for practical utility on a force-pump. In this I think he has succeeded most admirably. Several styles of apparatus have been made by him for using his nozzle in practical work both in doors and out. Those designed for outdoor work have especial reference to the destruction of insects. How useful these may prove I would not venture an opinion, not having had a chance to use them in actual work, but of the fact that his nozzle will produce spray as fine or as coarse as can possibly be desired there is not the possibility of a doubt, and this, too, without any waste of liquid.

"The pump used on his machines is a single cylinder double action force-pump of extremely simple mechanism and of great power and durability.

"The nozzle (in which lies all the mechanism which he can really call his own invention) is very simple. It consists of a brass nipple three-quarters to 1 inch in length, pierced by a small hole varying in diameter according to the amount of spray desired. This nipple screws on to the discharge pipe and on its outer end is screwed a chamber three-quarters to 1 inch in diameter and 3 inches long. These dimensions have been determined by experiment. The nipple and chamber are made of brass. On the outer end of the chamber is soldered a wire gauze varying in size of mesh to suit size of orifice in nipple.

"The nipples tested by me were as follows:

No. 1. One sixty-fourth inch orifice projected spray 10 feet in straight line; discharged pint of liquid in 20 seconds; pressure could not be measured, but I think was 75 to 100 pounds in all the tests. Spray floated like mist.

No. 2. One thirty-second inch orifice projected spray little farther and little coarser; discharged 1 pint in 15 seconds.

No. 3. Five sixty-fourths inch orifice projected spray 18 feet; discharged 1 pint in 8 seconds; spray coarser than previous, but floated well in the air.

No. 4. One-eighth inch orifice projected spray 25 feet; discharged 1 pint in 5 seconds; still coarser, but fell in perfect mist, completely wetting soil.

"The apparatus tested by me was really yet in the experimental stage but gave very satisfactory results.

"The special features which commend this nozzle are that it is very simple, discharges spray farther in a straight line than any apparatus ever tested by me, and the capacity is practically unlimited.

"The complete machines which Mr. Nixon had made and were tested by me were as follows:

"No. 1. Sulky cart, drawn by horse, which also furnished motive power to pump by gearing from wheel. This machine as timed by me was capable of going over 21 acres of ground in eight consecutive hours, and completely spraying any low crop. Tank holds 70 gallons; pump arranged inside and so rigged with safety valve that pressure could be made to suit requirements of the nozzle used. This machine could also be used as a hand-pump by throwing out of gear and putting on a lever.

"No. 2. Is a hand machine on trucks with a small rest wheel in front. Tank holds 40 gallons and can be used for all ordinary purposes of spraying beds and lawns; also mounted in a wagon would be very serviceable for spraying orchards.

"No. 3. Is a small machine, 15-gallon tank, intended for use indoors."

The second machine is the invention of Mr. John Bowles, of Washington, D. C., and is used for the purpose of vaporizing naphtha of grade 77. Experiments made by Mr. Bowles and witnessed by Mr. Howard with this machine upon the Web-worm were successful in killing the worms, leaving the foliage uninjured. Fig. 27 shows the machine in section. Mr. Bowles' description is as follows:

"The mechanism employed for the purpose of applying the oil in the form of spray consists, essentially, of an oil-compresser, combined with an air-compresser, so that both may be actuated by the same effort, the leverage being adjusted so that the greater pressure may be applied to the oil-compresser, and the communicating together of the streams of oil and air at a nozzle for their discharge.

The form of machine shown meets these requirements. S is an oil-tank, that, for convenience, may be mounted on wheels. P is a bellows, attached to the tank, and actuated by the board *h*, by means of the handle, V, being pivoted to the top of the tank at U. An oil-pump is shown, within the chamber of the bellows, having a suction-pipe, *s*, extending into the oil, and a discharge-pipe, *w*, connecting with the oil-pipe E, while the air discharged from the bellows passes through the air-pipe D,

the oil-pipe being within the air-pipe, and both pipes meeting at the point of discharge, at the nozzle. The plunger or piston of the oil-pump is actuated by a rod

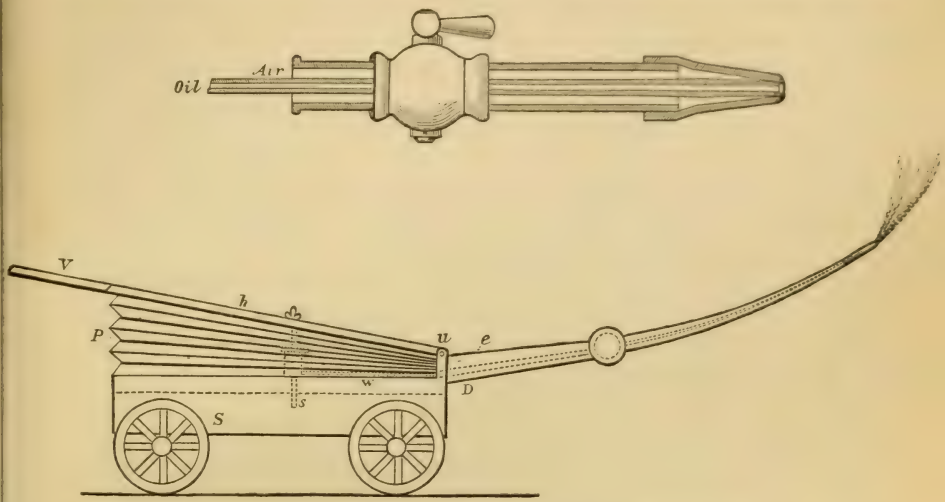

Fig. 27.—Atomizing machine invented by John Bowles, Washington, D. C.

pivoted to the board *h*, at a point that will give the oil-compresser such increased leverage as may be demanded for its proper discharge.

PRUNING AND BURNING.

The old and well-tried remedies of pruning or burning, or pruning and burning, will answer every purpose against the Web-worm in ordinary seasons, where it is thoroughly done and over a whole neighborhood. It must, however, be done upon the first appearance of the webs on the trees, and not, as was done by the Parking Commission of this city last season, after the first brood of worms had attained their full growth and many had already transformed to pupæ. The nests at that time had assumed large proportions, and their removal entire injured the appearance of many young trees. Then, too, they were piled upon an open wagon, which was dragged for many hours around the streets, permitting a large proportion of the worms to escape.

On the first appearance of the webs, which should be looked for with care, they should be cut off or burned off, and if cut off they should be burned at once. The "tree pruners," manufactured for the trade and well known to all gardeners, answer the purpose admirably.

The customary method of burning the nests is by means of rags saturated with kerosene or coal-tar and fastened to the tip of a long pole. An old sponge has been substituted to advantage for the rags, but probably the best substitute for this purpose is a piece of porous brick. In a pointed communication published in the *Evening Star*, of August 21, Major Key, agent of the Humane Society, thus describes the making of a brick torch: "Take a piece of soft brick, commonly

termed salmon brick, trim it to an egg shape; then take two soft wires, cross them over this brick, wrapping them together around the opposite side so as to firmly secure it; now tie this end to a long stick, such as the boys get at the planing mills, by wrapping around it; then soak the brick in coal-oil, light it with a match, and you are armed with the best and cheapest weapon known to science. Holding this brick torch under the nests of caterpillars will precipitate to the sidewalk all the worms on one or two trees at least from one soaking of the brick, and it can be repeated as often as necessary. Then use a broom to roll them under it and the work will be done, the controversy ended, and the tree saved."

Asbestos may also be used to advantage, and a little thorough work with some simple torch *at the right time* will in nearly every case obviate the necessity of the more expensive remedies later in the season, when the worms of the first brood have grown larger or when the second brood has appeared.

MULCHING.

After a bad caterpillar year, a little judicious raking together of leaves and rubbish around the trunks of trees which have been infested, at the time when the worms of the second brood are about full-grown and before they commence to wander, will result in the confinement of a large proportion of the pupæ to these limited spaces, where, with a little hot water or a match, they can readily be destroyed during the winter. Many of the caterpillars, of course, reach the ground by dropping purposely or falling accidentally from the branches, but the great majority descend by the trunk, and, finding the covenient shelter for pupation ready at the foot of the tree, go no farther. This has been tested on the Department grounds the past season, and is mentioned as a method of riddance supplementary only to others.

INFLUENCE OF TREE-BOXES.

However necessary it may be in cities to protect trees, by means of tree-boxes, against bodily injury, chiefly committed by mischievous boys and loafers, such protection should only be afforded for a limited time, or long enough for the growing tree to attain a sufficient thickness to prevent its being broken by any ordinary accident. After such a thickness has been reached the boxes ought to be discarded. They are unnatural, and both injurious to the tree and unpleasant to the eye. A great number of trees are forever injured by such boxes, and the great increase of some kinds of insects is solely due to them. For instance, the Maple Bark-borer (*Trochilium acerni*) is almost solely confined to the injured bark of maple trees protected by boxes, and is scarcely ever found in normally growing trees. Such tree-boxes furnish good shelters for the formation of cocoons, and afford winter quarters for many noxious insects. The Web-worm under consideration makes excellent use of them. A small Box Elder, with a trunk of about 4 inches in diame-

ter—a tree strong enough to thrive without protection—had been inclosed by the usual form of a wooden tree-box. This was removed, and the inside of the box and the collected rubbish in it was carefully investigated by one of our assistants, Mr. Otto Lugger. This is the result: 74 cocoons of *H. cunea;* 43 egg-masses of *Orgyia leucostigma;* 4 cocoons of *Acronycta americana*, and 1 pupa of *Anisota rubicunda*, besides innumerable old and empty pupal skins of these and other insects. It is to be added in this connection that this tree grew in a park in Baltimore, and was not as badly infested as trees in Washington.

A young tree in a tree-box ought to be firmly fastened at the top to all sides of the box, and this by means of flexible bands, to be renewed from time to time. In this manner a high wind would be prevented from producing any friction of the trunk or branches against the edges of the box. After the tree attains a size of 2 inches in diameter the tree-box ought to be removed, and the members of the city police should be instructed to pay especial attention to their further necessary protection. The shelter afforded by the wooden tree-boxes is, in my judgment, the prime reason why the Web-worm has become such a great nuisance in Washington. They should either be discarded entirely after the trees have attained a trunk diameter of 4 inches, and heavy penalties enacted for hitching horses or for in any way cutting or defacing the trunk; or, what would perhaps be safer, and certainly very much less objectionable, they should be replaced as soon as possible by round iron ones like those now in use on Fifteenth street, between New York avenue and K street. These will afford less shelter for cocoons, and are in every way less objectionable.*

WHITEWASHING OF TRUNKS.

Whitewash covers a multitude of sins; but sins should not be covered up, they should be eradicated, which a simple whitewashing will not do. A whitewashed tree is an eyesore, and whole rows of them, or even groves in parks treated in such a way, produce a sight to be deplored by all people admiring the beauty of nature. One is forcibly reminded of a grave-yard when walking through some of the Washington streets after sunset; the white trunks glisten like the broken shafts in an old cemetery. If the trunks of trees must be covered with lime at all, why not choose at least a color more in harmony with nature, the color of the bark for instance? There is no necessity, however, in Washington to whitewash the trunks of our shade trees. As a protection against flat and round-headed borers (species of *Chrysobothris* and *Saperda*) it is of value when a certain proportion of arsenic is mixed with it; but the principle "what is sauce for the goose is sauce for the gander" does not apply in this instance, and as a remedy for the Web-worm it is practically useless. Only one of the insects mentioned can be in any way be lessened by this practice, and that is the species that Washingtonians are just now least concerned with, viz, the Orgyia.

* Since this was written a very simple and excellent mode of protection has been adopted by the Parking Commission of the District, viz, encircling the trunks with woven galvanized wire.

It is very questionable whether the whitewash will destroy its eggs, but there is every reason to believe that the friction of the brush and the disengaging of many of the cocoons will cause the destruction of a certain number. On our larger trees the greater number of these cocoons are never reached by such whitewashing, because they are upon the higher limbs. The Web-worm cannot be affected by the practice, as the hibernating chrysalids and cocoons are not found upon the trunks. As against these negative results of whitewashing, however, we must put the injurious results that follow indirectly; because a great many of the enemies of the defoliators are destroyed by whitewashing. This is particularly the case with the egg-masses of spiders and many of the softer and more delicate cocoons of parasites.

BIRDS: THE ENGLISH SPARROW.

All four of these insects have a certain immunity from the attacks of birds: No. 1 by virtue of an offensive odor; No. 2 by the protection of its bag; Nos. 3 and 4 by the protection afforded by the hairs of the caterpillars, which are also mixed into their cocoons. A few native birds we have seen occasionally feed upon Nos. 3 and 4, but the English sparrow, to which, being emphatically a city bird, we should look for help, has never been known to attack any of them. In fact, we noticed and announced many years ago that in some of the northern cities (as Boston and Philadelphia) the increase of the Orgyia was indirectly a result of the increase of the English sparrow, which feeds in the breeding season upon smooth worms less harmful to our trees, and thus gives better opportunity for the rejected Orgyia to increase, a result still further promoted by the habit of driving away the native birds which the English sparrow is known to have. The same reasoning will hold true in respect of the Web-worm; and, putting all sentiment aside, we may safely aver that this bird is an impediment rather than an aid in preserving our trees from their worst insect defoliators. There is every reason to believe that the Bag-worm is carried, when young, from tree to tree upon the claws and legs of the bird, and its dissemination is thus aided and its destruction rendered more difficult; while the yellow suspended cocoons of the *Meteorus hyphantriæ* (the most important of the parasites of the Web-worm) are sought by the sparrow, probably being mistaken for grains of wheat.

While our feathered friends, owing to the sparrow's pugnacity, are now things of the past, and can only be seen in the spring when they pass through the cities in their migrations to more peaceable nesting places, yet something might be done to encourage their stay. Nesting places might be provided for them not alone by bird-boxes, which, good in themselves, are at once occupied by the English sparrow; they must be afforded safer and natural quarters. This has been successfully achieved in portions of Europe and by the following very simple

methods: First, a number of low but dense trees and bushes, forming in themselves fine-looking groups, are surrounded by dense and thorny hedges, to prevent cats and other enemies of birds from entering the inclosed space. Second, in the crotches of taller trees, and chiefly in the first crotch, bundles of thorny branches are fastened in such a way as to prevent cats from climbing above them. Such bundles would not look well during the winter, but they could then be removed to be replaced by fresh ones in the early spring. A broad strip of tin would, perhaps, answer the same purpose, but would not, at first, be as attractive to the birds themselves. A strict law against the use of slings, stones, and other weapons in the hands of the boys must, of course, be strictly enforced. In a very short time birds of various kinds will discover the safety of such places, and utilize them. Even if these birds should not alone avail against the ravages of insects, they would do good service, and their presence would pay for the little trouble of an invitation to them.

THE FUTURE OF OUR TREES—PRUNING.

Before closing this article it may be well to call attention to another danger from which our shade trees are threatened in the future. We refer to the reckless and almost cruel pruning which has in the past been indulged in, and which, if we are rightly informed by Mr. Saunders, the Parking Commission find it very difficult to prevent. No one looking to the future of our shade trees can have witnessed without indignation the gangs of careless men who periodically go through our streets cutting, hacking, and lopping indiscriminately and without intelligence the limbs of the trees until they have become on many of the older streets deformed and unsightly objects. The result of senseless pruning is easily seen on some of these older streets as compared with the trees in our parks which have been more often left alone and more intelligently pruned. Street shade trees should be pruned from below and not lopped off from the top, so that in the future there will result a tall straight trunk, not intercepting the view of the buildings from the street and yet furnishing the desired shade and beauty. The trees of such cities as Cambridge, New Haven, Saratoga, &c., may be cited by comparison with what ours are fast becoming. But there is another side to this question which justifies us in calling attention to it in this connection. To use the language of our Seventh Report on the Insects of Missouri, published in 1874, in treating of the Flat-headed Borer (*Chrysobothris femorata*), one of the most destructive borers of our trees: "Many a fine orchard tree, and many more city shade trees, receive their death shock from the reckless sawing off of limbs without effort being made to heal the wounds by coating with grafting wax, clay, or other protecting substances. Around such an unprotected sawed limb, as around the frustrum of a felled tree, the rain and other atmospheric in-

fluences soon begin their work of causing decay between the bark and the solid wood; and this is but the forerunner of greater injury by insects which are attracted to the spot, and which, though hidden meanwhile from view, soon carry the destruction from the injured to the non-injured parts."

There is, in fact, more danger that our trees in future (especially the Soft Maple) will begin to fall and perish from the ravages of Borers, as a result of reckless pruning, than that they will ever be seriously or permanently injured by leaf-eaters. These last, as we have seen, may be overcome, but the Borers are not only more deadly but more difficult to manage.

TREES WHICH ARE UNINJURED.

I have already indicated a few of the trees which are most subject to injury from this Web-worm. There is also quite a list of trees which are either very little affected or are never attacked, and in this connection it may be well to mention a few of these which are, not only on this account but in every other way, desirable for shade trees and should be strongly urged upon the Parking Commissioners as substitutes for those, like the Box Elders, which are so seriously affected. In this list of desirable trees which have immunity I would mention:

Tulip tree (*Liriodendron tulipifera* L.).
Sweet Gum (*Liquidambar styraciflua* L.).
Sweet Buckeye (*Æsculus flava*, Ait).
Ohio Buckeye (*Æsculus glabra*, Willd.).
The Maples (*Acer rubrum*, *A. saccharinum*, *A. pseudoplatanus*, and *A. dasycarpum*).
Honey Locust (*Gleditschia triacanthus* L.).
Kentucky Coffee Tree (*Gymnocladus canadensis*, Lamb).
Sour Gum (*Nyssa multiflora*, Wangerh.).
Beech (*Fagus ferruginea*, Ait).
Yews (*Taxus* spec.).

GOOD AND BAD EFFECTS OF OUR TREES.

The beauty of Washington is very greatly enhanced by its shade trees, and the Parking Commission deserve very great credit for the gigantic work they have carried out in the last fifteen years. But while these trees are and ought to be in the future an unending source of pleasure and healthfulness, yet here, as is so often the case, the good has some corresponding evil. This last, however, may be easily avoided. We hear much of malarial troubles in Washington, and the Potomac flats come in for nearly the entire blame. During the month of October our streets are constantly covered with fallen leaves from our shade trees, eddying and whirling about and carried by every heavy

rain into the sewer traps. Now, however vigilant the authorities may be during the heat of summer in cleaning out these traps, at the approach of cold weather the necessity for their frequent cleaning is supposed to be removed. As a consequence of this, vast masses of black, decomposing, and reeking leaves are left to fester during the late fall and early winter, and even through the whole winter, sending forth their injurious and insidious emanations from every street corner. From personal experience we are convinced that this is a source of much sickness hitherto almost entirely overlooked, and it behooves the authorities to have the traps on all the tree-planted streets thoroughly cleaned out immediately after the trees have become essentially bare.

PROSPECTS THE COMING SEASON.—CONCLUSION.

From the habits of the Orgyia as compared with the Web-worm there is good reason to believe that the former will become in the future more and more numerous and more and more of a nuisance, just as it has become the most grievous pest in Boston and Philadelphia and other cities where the trees are older. As to the prospects of a repetition of the Web-worm nuisance the coming season, the probabilities are that it will be very much less troublesome than it was in 1886. It is almost a universal rule in insect life that abnormal increase of a plant-feeding species is followed by a sudden check. This is due to two causes: *First*, the great multiplication of the parasites and natural enemies of the species which such undue increase permits; *secondly*, to the greater feebleness and tendency to disease resulting from insufficient food, which is a very general accompaniment of such undue increase. From the diseased condition in which the bulk of the last generation of the Web-worm was found, and from the great increase in its parasites that we know to have taken place from actual observation, we may safely expect exceptional immunity the present year.

SOURCE OF ILLUSTRATIONS.

Plate I is from a photograph. Figures 1, 2, 3, 4, 5, 6, and 11 are republished from former Government reports by the author. Figures 7, 12, 13, 14, 15, 20, 21, 22, and 26 are from the author's Reports on the Insects of Missouri. Figures 9, 10, and 25 are from other miscellaneous papers by the author. Figure 8 is from Hubbard, and figure 16 is from Glover; while figures 17, 18, 19, 23, 24, and 27 were drawn for this Bulletin and for our Annual Report as Entomologist to the Department of Agriculture for 1886.